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USER'S GUIDE FOR MODELS OF DREDGED MATERIAL DISPOSAL IN OPEN WATER

by

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Mathematical models that account for the physical processes determining the short-term fate of dredged material disposed at open-water sites provide estimates of suspended sediment concentrations in the receiving water and the initial deposition pattern and thickness of material on the bottom. Two such models were developed under the US Army Corps of Engineers Dredged Material Research Program to handle both instantaneous dumps and continuous discharges. A third model using features of the two earlier models has been constructed to handle a semicontinuous disposal operation from a hopper dredge. These models are known as DIFID (Disposal From an Instantaneous Dump), DIFCD (Disposal From a Continuous Discharge), and DIFHD (Disposal From a Hopper Dredge). The use and limitations of each are presented along with theoretical discussions. Example applications are given in the appendices to illustrate the setup of input data and the display of output from the models.

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19. ABSTRACT (Continued).

Appendices A, B, and C present example applications for DIFID, DIFCD, and DIFHD, respectively; and Appendices D, E, and F give the input data formats for DIFID, DIFCD, and DIFHD, respectively.

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PREFACE

The model refinements reported herein were made during the period January 1985-December 1987 by personnel of the Hydraulics Laboratory (HL) of the US Army Engineer Waterways Experiment Station (WES) as part of the Dredging Operations Technical Support Program (DOTS) Dredged Material Management Task on Automated Dredging and Disposal Alternatives Management System (ADDAMS) and on Long-Term Management of Dredged Material Disposal. DOTS is sponsored by Headquarters, US Army Corps of Engineers, and managed at WES by the Environmental Laboratory (EL) under the Environmental Effects of Dredging Programs (EEDP).

Dr. Billy H. Johnson, Waterways Division (WD), HL, conducted the study and prepared this user's guide under the general supervision of Messrs. Frank A. Herrmann, Chief, HL, and Marden B. Boyd, Chief, WD. This report was edited by Mrs. Marsha C. Gay, Information Technology Laboratory, WES.

Dr. Robert M. Engler, EL, is the EEDP Program Manager, and Mr. Thomas R. Patin, EL, is the DOTS Coordinator. Dr. Paul R. Schroeder, Water Resources Engineering Group (WREG), EL, managed the project under the general supervision of Dr. F. Douglas Shields, Acting Chief, WREG, EL; Dr. Raymond L. Montgomery, Chief, Environmental Engineering Division, EL; and Dr. John Harrison, Chief, EL.

COL Larry B. Fulton, EN, is the Commander and Director of WES. Dr. Robert W. Whalin is the Technical Director.

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CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
square feet	0.09290304	square metres

USER'S GUIDE FOR MODELS OF DREDGED MATERIAL DISPOSAL IN OPEN WATER

PART I: INTRODUCTION

Background

Origin

1. Three models for computing the fate of dredged material are discussed. The instantaneous dump model DIFID (Disposal From an Instantaneous Dump) and the continuous discharge model DIFCD (Disposal From a Continuous Discharge) were developed by Brandsma and Divoky (1976) for the US Army Engineer Waterways Experiment Station (WES) under the Dredged Material Research Program (DMRP). Much of the basis for these two models was provided by earlier model development by Koh and Chang (1973) for the barged disposal of wastes in the ocean. That work was conducted under funding by the US Environmental Protection Agency (EPA) in Corvallis, OR. The third model is the hopper dredge model DIFHD (Disposal From a Hopper Dredge), which treats disposal from a hopper dredge containing several bins. This model is a combination of the instantaneous dump and the continuous discharge models and was constructed in the Hydraulics Laboratory at WES. These three models, as described in this report, are included in the ADDAMS (Automated Dredging and Disposal Alternatives Management System) program with an interactive routine for data entry (Hayes et al., in preparation).

Purpose

2. Annually, millions of tons of dredged material from streams, estuaries, and coastal waters are disposed in the aquatic environment. The disposal site environment, the composition of the disposed material, and the method of disposal are the major factors in the determination of the short-term location and concentration of dredged material. Mathematical models of the physical processes determining the fate of the disposed material can be used to provide an estimate of concentrations in the receiving water as well as the initial deposition pattern of material on the bottom. Estimates of water column concentrations are often needed to determine mixing zones. The initial deposition pattern of material on the bottom is required in long-term

sediment transport studies which assess the potential for erosion, transport, and subsequent redeposition of the material. Such models can also serve as a valuable aid in field monitoring programs.

Limitations

3. These models simulate movement of the disposed material as it falls through the water column, spreads over the bottom, and finally is transported and diffused as suspended sediment by the ambient current. DIFID is designed to simulate the movement of material from an instantaneous dump which falls as a hemispherical cloud. Thus, the total time required for the material to leave the disposal vessel should not be greater than the time required for the material to reach the bottom. DIFCD is designed to compute the movement of material disposed in a continuous fashion at a constant discharge rate. Thus, it can be applied to pipeline disposal operations in which the discharge jet is below the water surface or perhaps to the discharge of material from a single bin of a hopper dredge. If the initial direction of disposal is vertical, either the disposal source must be moving or the ambient current must be strong enough to result in a bending of the jet before the bottom is encountered. DIFHD has been constructed to simulate the fate of material disposed from stationary hopper dredges. Here, the normal mode of disposal is to open first one pair of doors, then another, until the complete disposal is made, which normally takes on the order of a few minutes to complete. DIFHD should not be applied to disposal operations that differ significantly from that described.

4. All three models require that the dredged material be broken into various solid fractions with a settling velocity specified for each fraction. In many cases, a significant portion of the material falls as "clumps." This is especially true if the dredging is done by clamshell and can be true in the case of hydraulically dredged material if consolidation takes place in the hopper during transit to the disposal site or if consolidated clays are dredged. The specification of a clump fraction is rather subjective. Therefore, the inability to characterize the disposed material accurately in some disposal operations prevents a quantitative interpretation of model results in those operations. In addition, it should be noted that the disposed material is expected to behave as a dense liquid. This will be true only if the

material is composed of primarily fine-grained solids. Thus, the models should not be applied to the disposal of purely sandy material.

5. As noted, a settling velocity must be prescribed for each solid fraction. A basic assumption is that unless the fraction is specified as being cohesive, in which case the settling velocity is computed as a function of concentration, the settling is considered to occur at a constant rate.

6. When the models are applied, computations are referenced to a horizontal grid with a square spacing, and a variable water depth over the grid is allowed. However, the collapse of the dredged material cloud on the bottom does not consider the variable depth, although an average bottom slope at the impact point can be specified as input data. Even though the effect of a bottom slope has been incorporated, a basic limitation still exists in that the bottom can slope in only one direction over the collapsed region; i.e., bottom collapse on a "mound" where the collapsing cloud runs down the sides is not treated. For controlled disposal operations in which material is disposed into bottom depressions, both DIFID and DIFHD have been modified to allow for the collapse of the bottom cloud in a rectangular hole.

7. A major limitation of these models is the basic assumption that once solid particles are deposited on the bottom, they remain there. Therefore, the models should be applied only over time frames in which erosion of the newly deposited material is insignificant.

8. The passive transport and diffusion phase in all three models is handled by allowing material settling from the descent and collapse phases to be stored in small Gaussian clouds. These clouds are then diffused and transported at the end of each time-step. Computations on the long-term grid are made only at those times when output is desired.

Previous Applications

9. Most of the applications of the disposal models to date have been of a generic nature; i.e., default values of model coefficients have been used. Such applications have been made at disposal sites near the Hawaiian Islands (Johnson and Holliday 1977), San Diego Harbor*, San Francisco Bay (Trawle and

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* B. H. Johnson. 1979 (Nov). "Application of the Instantaneous Dump Dredged Material Disposal Model to the Disposal of San Diego Harbor Material at the 45- and 100-Fathom Disposal Sites," In-house Report, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Johnson 1986a), Puget Sound (Trawle and Johnson 1986b; Adamec et al. 1987), and Long Island Sound.* Verification efforts by Johnson and Holliday (1978) using data collected by Bokuniewicz et al. (1978) were conducted for disposal operations at the Duwamish disposal site in Elliott Bay near Seattle, WA, in the New York Bight, and in Lake Ontario. However, the data available were limited, and the disposal operations in Lake Ontario and the New York Bight did not fit the idealized operations assumed in the models. In addition, recent modifications made in the bottom collapse phase to better represent the dynamics of a radially expanding bottom surge will likely require different values of the collapse phase coefficients than those determined in the 1978 study.

10. In connection with the recent modeling of dredged material disposed in Puget Sound (Adamec et al. 1987), the latest version of DIFID has been applied using the data collected by Bokuniewicz et al. (1978) at the Duwamish disposal site. Results from this effort are presented in Part II.

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* B. H. Johnson. 1978 (Sep). "Application of the Instantaneous Dump Dredged Material Disposal Model to the Disposal of Stamford and New Haven Harbor Material from a Scow in the Long Island Sound," In-house Report, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

PART II: MODEL DESIGN

Theoretical Basis

11. In all three models the behavior of the material is assumed to be separated into three phases: convective descent, during which the disposal cloud or discharge jet falls under the influence of gravity; dynamic collapse, occurring when the descending cloud or jet either impacts the bottom or arrives at a level of neutral buoyancy where descent is retarded and horizontal spreading dominates; and passive transport-dispersion, commencing when the material transport and spreading are determined more by ambient currents and turbulence than by the dynamics of the disposal operation. Figures 1, 2, and 3 illustrate these phases for DIFID, DIFCD, and DIFHD, respectively.

Convective descent

12. In DIFID, a single cloud that maintains a hemispherical shape during convective descent is assumed to be released. Since the solids concentration in discharged dredged material is usually low, the cloud is expected to behave as a dense liquid; thus, a basic assumption is that a buoyant thermal

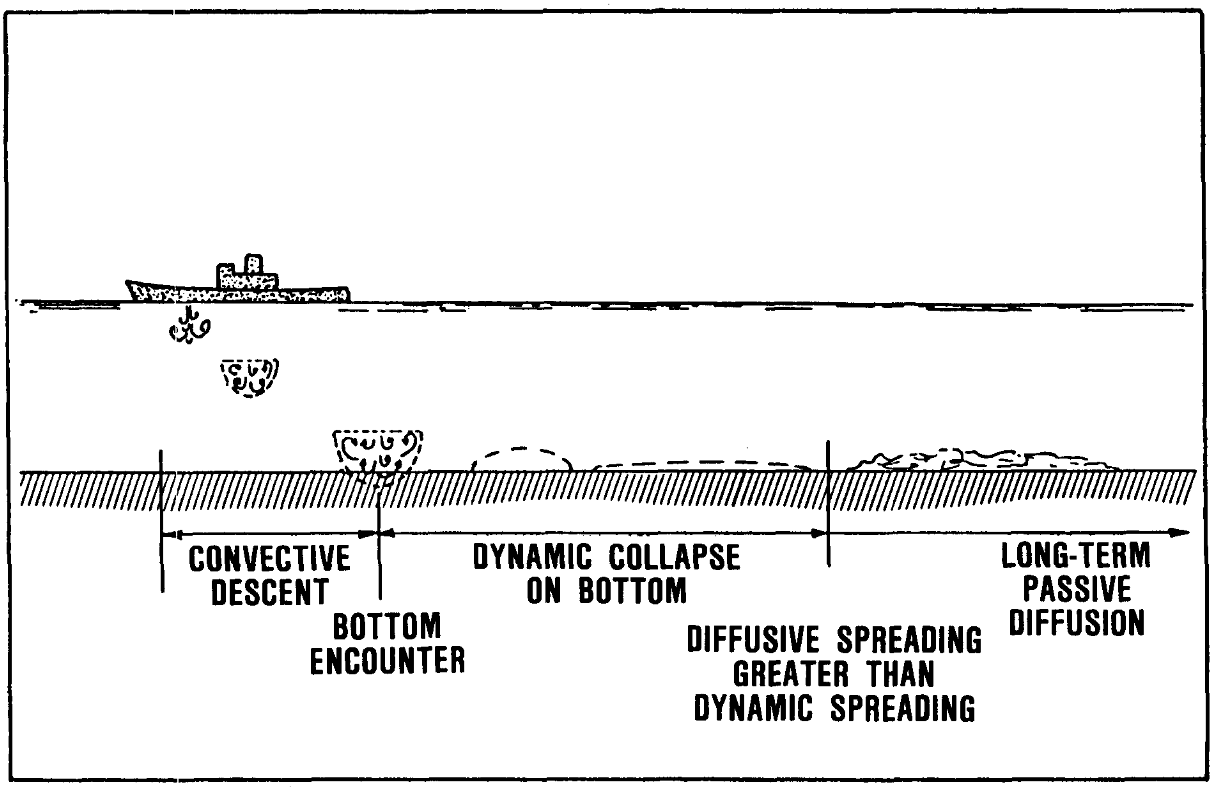


Figure 1. Illustration of idealized bottom encounter after instantaneous dump of dredged material (from Brandsma and Divoky 1976)

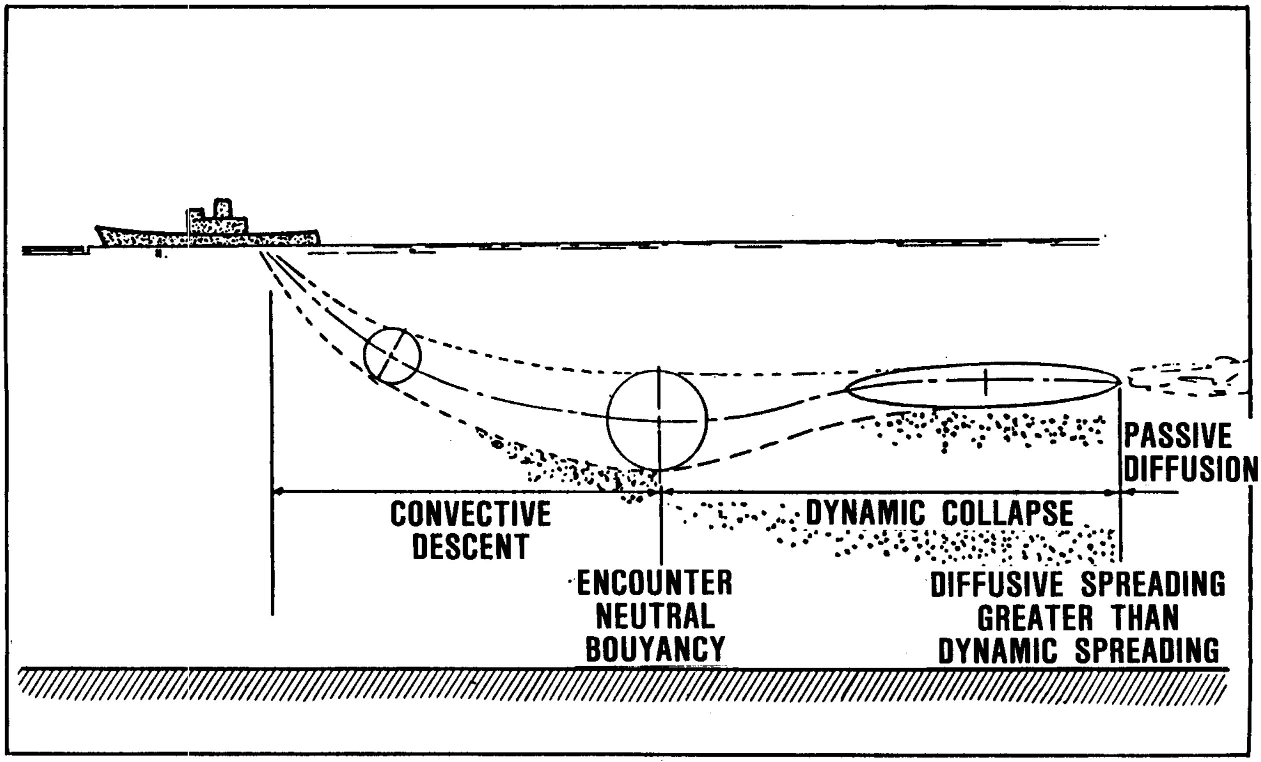


Figure 2. Idealized jet discharge from moving vessel. Cross sections are shown at three stages of the plume. A heavy class of particles is depicted settling out of the plume at an early stage. Lighter particles are shown settling during the collapse phase (from Brandsma and Divoky 1976)

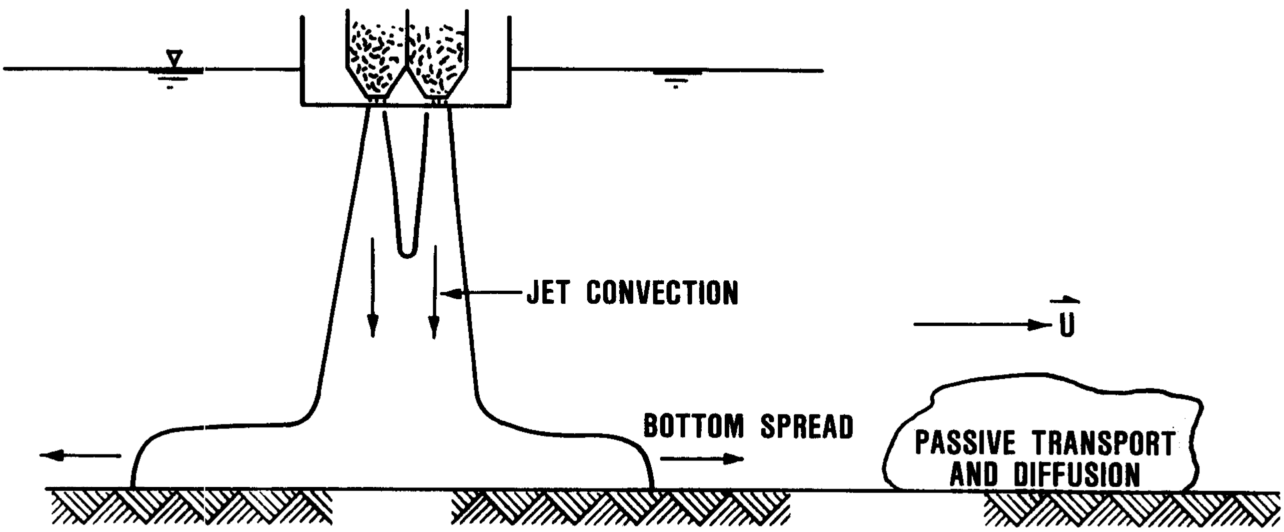


Figure 3. Illustration of idealized disposal from a hopper dredge

analysis is appropriate. The equations governing the motion are those for conservation of mass, momentum, buoyancy, solid particles, and vorticity. These equations are straightforward statements of conservation principles and will not be presented here. Details are presented in Koh and Chang (1973) and Brandsma and Divoky (1976). It should be noted that the entrainment coefficient associated with the entrainment of ambient fluid into the descending hemispherical cloud is assumed to vary smoothly between its value for a vortex ring and the value for turbulent thermals. Model results are quite sensitive to the entrainment coefficient, which in turn is dependent upon the material being disposed (the higher the moisture content, the larger the value of the entrainment coefficient). Laboratory studies by Bowers and Goldenblatt (1978) have resulted in analytical expressions for the entrainment, drag, and added mass coefficients as functions of the moisture content. These have been incorporated into DIFID.

13. In both DIFCD and DIFHD, the flow phenomenon near the discharge opening, e.g., a pipeline or the bottom doors of a hopper dredge bin, is that of a sinking momentum jet. Basic assumptions in the formulation of the conservation equations for the jet convection phase are that the jet cross section remains circular and that velocity, density, and material concentration distributions may be approximated by "top hat" profiles. Entrainment is assumed to be composed of a combination of momentum jet entrainment and entrainment experienced by a two-dimensional (2-D) thermal. Again, details concerning the governing equations and their solutions are given by Koh and Chang (1973) and by Brandsma and Divoky (1976).

Dynamic collapse

14. Whether by disposal as an instantaneous dump from a barge or scow, continuous discharge from a pipeline or moving vessel, or semicontinuous discharge from an essentially stationary hopper dredge, the disposed material cloud or jet grows during convective descent as a result of entrainment. Eventually, either the material reaches the bottom, or the density difference between the discharged material and the ambient water column becomes small enough for a position of neutral buoyancy to be assumed. In either case, the vertical motion is arrested and a dynamic spreading in the horizontal occurs.

15. In both the instantaneous dump model, DIFID, and the semicontinuous hopper dredge model, DIFHD, the basic shape assumed for the collapsing cloud is an oblate spheroid if collapse occurs in the water column and a general

ellipsoid for collapse on a sloping bottom. With the exception of vorticity, which is assumed to have been dissipated by the stratified ambient water column, the same conservation equations used in convective descent but now written for either an oblate spheroid or an ellipsoid are applicable. For the case of collapse on the bottom, a frictional force between the bottom and the collapsing cloud is included which accounts for energy dissipation as a result of the radial spreading as well as movement of the cloud centroid.

16. One major difference exists between the bottom collapse phases of DIFID and DIFHD. In DIFID the complete disposal strikes the bottom as a hemispherical cloud, whereas DIFHD models a semicontinuous disposal operation. In a hopper dredge disposal operation, one or more doors are opened together with remaining doors opened as the previous bins become empty. DIFHD handles such a disposal operation by treating the initial disposal as a continuous jet discharge. When the jet strikes the bottom, the collapse phase is handled by the collapse of an ellipsoid but with a continuous injection of material possessing the density and solid fraction concentrations computed at the end of the jet convection phase. If several bins discharge simultaneously, the initial size of the cloud in collapse is adjusted by a representative distance, e.g., half the distance between bin doors.

17. As the jet plume of a continuous jet discharge that does not strike the bottom moves far downstream from the discharge point, its velocity approaches that of the ambient fluid, and its behavior is more like a 2-D thermal than a jet. The cross section of the 2-D thermal is assumed to have the shape of an ellipse. As in DIFID and DIFHD, the governing equations in DIFCD represent the conservation of mass, momentum, buoyancy, and solid particles, with a friction force included if the bottom is encountered.

Transport-diffusion

18. The passive transport-dispersion phase is treated the same in all three models. When the rate of spreading in the dynamic collapse phase becomes less than an estimated rate of spreading due to turbulent diffusion in both the horizontal and vertical directions, the collapse phase is terminated. During collapse, solid particles can settle as a result of their fall velocity. As these particles leave the main body of material, they are stored in small clouds that are characterized by a Gaussian concentration and position in the water column, i.e.,

$$C = \frac{m}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z} \exp\left\{ -\frac{1}{2}\left[\frac{(x - x_o)^2}{\sigma_x^2} + \frac{(y - y_o)^2}{\sigma_y^2} + \frac{(z - z_o)^2}{\sigma_z^2}\right]\right\} \quad (1)$$

where

m = total mass of cloud, ft^3

$\sigma_x, \sigma_y, \sigma_z$ = standard deviations

x,y,z = spatial coordinates

x_o, y_o, z_o = coordinates of cloud centroid

At the end of each time-step, each cloud is advected horizontally by the input velocity field. The new position of the cloud centroid is determined by

$$x_{o_{new}} = x_{o_{old}} + u \cdot \Delta t$$
$$z_{o_{new}} = z_{o_{old}} + w \cdot \Delta t \quad (2)$$

where

u,w = local ambient velocities, fps

Δt = long-term time-step, sec

19. In addition to the advection or transport of the cloud, the cloud grows both horizontally and vertically as a result of turbulent diffusion. The horizontal diffusion is based upon the commonly assumed four-thirds power law. Therefore, the diffusion coefficient is given as

$$K_{x,z_{new}} = A_L L^{4/3} \quad (3)$$

where A_L is an input dissipation parameter and L is set equal to four standard deviations. The expression for the horizontal growth of a cloud then becomes

$$\sigma_{x,z_{new}} = \sigma_{x,z_{old}} \left(1 + 4^{4/3}\,\frac{2}{3}\,\frac{A_L \Delta t}{\sigma_{x,z_{old}}^{2/3}}\right)^{3/2} \quad (4)$$

20. Vertical growth is similarly achieved by employing the Fickian expression

$$\sigma_y = (2K_y t)^{1/2} \tag{5}$$

where

K_y = vertical diffusion coefficient

t = time since formation of the cloud

From Equation 5,

$$\frac{d\sigma_y}{dt} = K_y (2K_y t)^{-1/2} \tag{6}$$

and thus,

$$\sigma_{y_{new}} = \sigma_{y_{old}} + \frac{K_y}{\sigma_{y_{old}}} \Delta t \tag{7}$$

where K_y is a function of the stratification of the water column. The maximum value of K_y is input as a model coefficient and occurs when the water density is uniform.

21. If long-term output is desired at the end of a particular time-step, the concentration of each solid type is given at each grid point by summing the contributions from individual clouds to yield

$$C_T = (2\pi)^{-3/2} \sum_{i=1}^{N} \frac{m_i}{\sigma_{x_i}\sigma_{y_i}\sigma_{z_i}} \exp\left\{ -\frac{1}{2} \left[\frac{\left(x - x_{o_i}\right)^2}{\sigma_{x_i}^2} + \frac{\left(y - y_{o_i}\right)^2}{\sigma_{y_i}^2} + \frac{\left(z - z_{o_i}\right)^2}{\sigma_{z_i}^2} \right] \right\} \tag{8}$$

where N is the number of small clouds of a particular solid type and y (the vertical position at which output is desired) is specified through input data. This approach for the transport-diffusion phase follows the work of Brandsma and Sauer (1983). The surface and all solid boundaries are handled by assuming reflection from the boundaries.

22. In addition to the horizontal advection and diffusion of material, settling of the suspended solids also occurs. Therefore, at each net point the amount of solid material deposited on the bottom and a corresponding thickness are also determined. A basic assumption in the models is that once material is deposited on the bottom, it remains there; i.e., neither erosion nor bed-load movement of material is allowed. This is the primary theoretical limitation of the models that restricts their usefulness to the study of the short-term fate of discharged material.

Model Capabilities

23. These computer programs enable the computation of the physical fate of dredged material disposed in open water. The following discussion describes particular capabilities or special features of the codes. Unless a particular model is noted, the discussion is applicable to all three.

Disposal methods

24. DIFID models an instantaneous dump. If all the material leaves the disposal source within a few seconds, the assumption of an instantaneous dump is adequate. DIFCD models a continuous discharge. Pipeline disposal operations or perhaps hopper dredge disposal from a single bin where either the speed of the vessel or the ambient current is strong enough to result in severe bending of the convective descent jet can be modeled with DIFCD. If disposal is from a stationary semicontinuous source, DIFHD should be applied. With this model, the continuous nature of the discharge is allowed while the bottom collapse features of DIFID are retained that give the radial spread on the bottom observed by Bokuniewicz et al. (1978).

Ambient environment

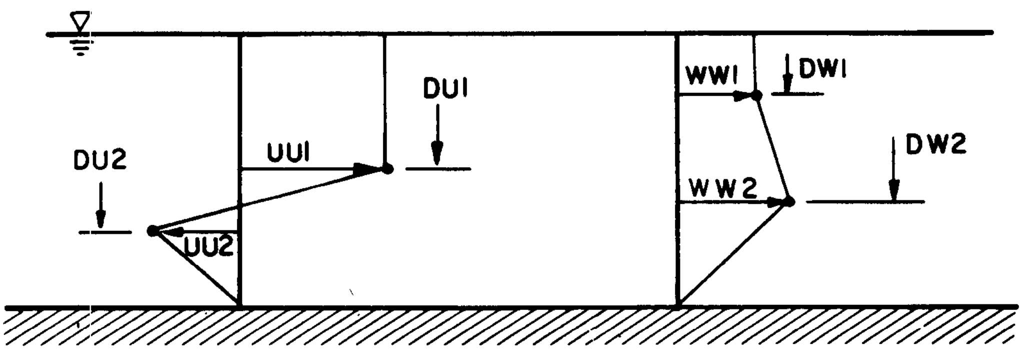
25. A wide range of ambient conditions are allowed in model computations. Conditions ranging from those found in relatively shallow and well-mixed bays and estuaries to stratified two-layer flow fields, found in estuaries where salt wedges are formed, can be handled. Bottom topography can be

entered as a constant value or can be varied from one grid cell to the next. As illustrated in Figure 4, two options of ambient current may be selected, with the simplest case being the time-invariant profiles shown in Figure 4a for a constant-depth disposal site. The ambient density profile is entered as a function of water depth at the deepest point in the disposal site.

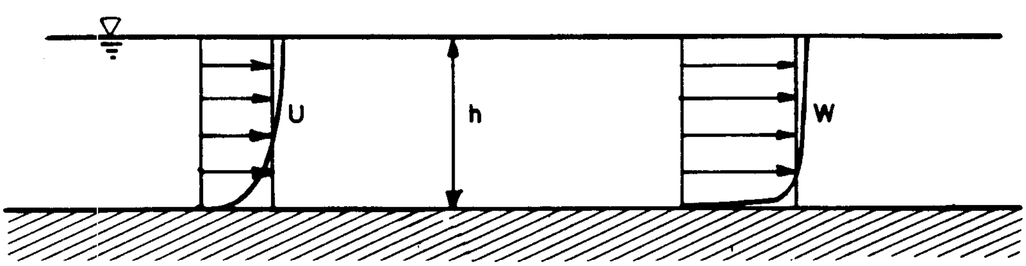
<u>Time-varying fall velocities</u>

26. If a solid fraction is specified as being cohesive, the settling velocity is computed as a function of the suspended sediment concentration of that solid type. The following algorithm is used:

$$V_s \begin{cases} = 0.0017 \quad \text{if} \quad C \leq 25 \text{ mg}/\ell \\ = 2.34 \times 10^{-5}\, C^{4/3} \quad \text{if} \quad 25 \leq C \leq 300 \text{ mg}/\ell \\ = 0.047 \quad \text{if} \quad C > 300 \text{ mg}/\ell \end{cases} \tag{9}$$



a. SIMPLE ORTHOGONAL VELOCITY PROFILES FOR CONSTANT DEPTH. APPLIED EVERYWHERE IN FIELD.



b. VERTICALLY AVERAGED VELOCITY PROFILES FOR VARIABLE DEPTHS WITH EQUIVALENT LOGARITHMIC PROFILES SUPERIMPOSED.

Figure 4. Various velocity profiles available for use in models (from Brandsma and Divoky 1976). Symbols are defined in Appendix D

where

V_s = settling velocity, fps

C = suspended sediment concentration, mg/ℓ

This approach is taken from Ariathurai, MacArthur, and Krone (1977).

Conservative constituent computations

27. The models allow for the dredged material to contain a conservative constituent with perhaps a nonzero background concentration of that constituent. Computing the resultant time-history of that concentration provides information on the dilution that can be expected over a period of time at the disposal site.

Output available

28. Through input data the user specifies the amount of output desired. Much of the input data required, e.g., the water depth field, are immediately printed after being read. At the end of the convective descent phase in DIFID, the location of the cloud centroid, the velocity of the cloud centroid, the radius of the hemispherical cloud, the density difference between the cloud and the ambient water, the conservative constituent concentration, and the total volume and concentration of each solid fraction are provided as functions of time since release of the material. Likewise, the location of the leading edge of the momentum jet, the center-line velocity of the jet, the radius of the jet, the density difference between material in the jet and the ambient water, the conservative constituent concentration, and the flux and concentration of each solid fraction are provided as functions of time at the end of the jet convection phase in DIFCD and DIFHD.

29. At the conclusion of the collapse phase in DIFID and DIFHD, time-dependent information concerning the size of the collapsing cloud, its density, and its centroid location and velocity as well as conservative constituent and solids concentrations can be requested. Similar information is provided by DIFCD at the conclusion of the jet collapse phase. It might be noted that these models attempt to perform the numerical integrations of the governing conservation equations in the descent and collapse phases with a minimum of user input. Various control parameters that give the user insight into the behavior of these computations are printed before the output discussed the preceding paragraph is provided. These are discussed in more detail in Appendices A, B, and C, where example applications of DIFID, DIFCD, and DIFHD, respectively, are presented.

30. At various times, as requested through input data, output concerning suspended sediment concentrations and solids deposited on the bottom can be obtained from the transport-diffusion computations. With the Gaussian cloud transport-diffusion scheme, only concentrations at the water depths requested are provided at each grid point. The volume of each sediment fraction that has been deposited in each grid cell is also provided. At the conclusion of the simulation, a void ratio specified through input data is used to compute the thickness of the deposited material from the following expression:

$$TH = \frac{1 + AVR}{AREA} \times VOL \tag{10}$$

where

TH = average depth of material deposited in the grid cell, ft

AVR = aggregate void ratio

AREA = grid cell area, ft^2

VOL = solids volume, ft^3

Program Organization and Size

31. All three models consist of approximately 3,000 lines of FORTRAN coding. Currently, the models are being run on both a CYBER computer and a personal computer, but no particular problems should occur in transferring the codes to other computer systems. Memory requirements will, of course, be dependent upon the size of the DIMENSION statements required for a particular simulation. Typical computation times are a few seconds per transport-diffusion time-step on a mainframe computer and a few minutes per time-step on a personal computer.

DIFID

32. DIFID is composed of a main program and 17 subroutines. The function of each is briefly discussed as follows:

a. AMBC: reads ambient data.

b. DUMP: controls computations for the convective descent phase.

c. DERIVD: computes the derivatives in the governing equations for the descent phase.

d. COLAPS: controls computations for the collapse of the cloud in the water column.

e. DERIVC: computes the derivatives in the governing equations for collapse in the water column.

f. BOTTOM: controls computations for the collapse of the cloud on the bottom.

g. DERIVB: computes derivatives in the governing equations for bottom collapse.

h. UW: reads time-varying velocities from TAPE7.

i. VEL: interpolates velocity input to provide horizontal components at a particular spatial location.

j. RUNGS: solves ordinary time-dependent differential equations using a fourth-order Runge-Kutta scheme.

k. BOOKS: transfers material from the descent and collapse phases into small clouds.

l. ACAD: updates the transport and diffusion of small clouds.

m. MAD: controls transport-diffusion computations.

n. PRINTC: controls printing of results from the transport-diffusion computations.

o. TRNSPT: computes the location one time-step ago of a particle occupying a grid point at the current time.

p. DINT: interpolates the water depth field to provide the water depth at a particular horizontal position.

q. VDIFCO: computes the vertical diffusion coefficient as a function of the stratification of the water column.

DIFCD

33. DIFCD is composed of a main program and 19 subroutines, many of which perform the same function as listed in the previous paragraph. However, there are differences in coding because all long-term computations are performed on each solid fraction separately in DIFID, whereas similar computations are performed simultaneously in DIFCD. The following subroutines are contained in DIFCD:

a. ESTGEO: reads geometry data and creates arrays to define water or land points.

b. INIT: reads much of the input data and initializes variables.

c. AMBC: determines new density profile at the discharge source.

d. JET: controls computations for the jet convection phase.

e. DERIVJ: computes derivatives in the governing equations for jet convection.

f. COLAPS: controls computations for collapse in the water column.

g. DERIVC: computes derivatives in the governing equations for collapse in the water column.

h. BOTTOM: controls computations for collapse on the bottom.

i. DERIVB: computes derivatives in the governing equations for bottom collapse.

j. UW: reads time-varying velocities from TAPE7.

k. VEL: interpolates velocity input to provide horizontal components at a particular spatial location.

l. RUNGSJ: solves ordinary space-dependent differential equations using a fourth-order Runge-Kutta scheme.

m. BOOKS: transfers material from jet convection and collapse into small clouds.

n. ACAD: updates the transport and diffusion of small clouds.

o. MAD: controls transport-diffusion computations.

p. TRNSPT: computes the location from which a particle occupying a grid point at the current time came.

q. PRINTC: controls printing of results from the transport-diffusion computations.

r. DINT: interpolates the water depth field to provide the water depth at a particular horizontal position.

s. VDIFCO: computes the vertical diffusion coefficient as a function of the stratification of the water column.

DIFHD

34. DIFHD is composed of the jet convection portion of DIFCD and the collapse and transport-diffusion portions of DIFID. Of course, additional coding has been added throughout to handle the semicontinuous nature of a hopper dredge disposal that strikes the bottom vertically with a subsequent radial spreading of the material on the bottom. The 18 subroutines composing DIFHD are listed as follows:

ESTGEO INIT JET DERIVJ	Same as in DIFCD
COLAPS BOTTOM DERIVC UW VEL	Same as in DIFID
RUNGSJ	Same as in DIFCD

RUNGS
BOOKS
ACAD
MAD
TRNSPT — Same as in DIFID
PRINTC
DINT
VDIFCO

Assembly of Input Data

35. Depending upon the complexity of ambient conditions at the disposal site, the preparation of input data can range from requiring the application of a vertically averaged hydrodynamic model to provide velocity fields to an entire input data setup of perhaps 20-25 cards as illustrated in the examples presented in Appendices A, B, and C. Input data can be grouped into (a) a description of the ambient environment at the disposal site, (b) characterization of the dredged material, (c) data describing the disposal operation, and (d) model coefficients. Each is discussed in the following paragraphs. Appendices D, E, and F provide formatted listings of the input data requirements of DIFID, DIFCD, and DIFHD, respectively.

Disposal site data

36. The first task in applying the models is constructing a horizontal grid over the disposal site. The number of grid points should be kept as small as possible but large enough to extend the grid beyond the area of interest at the level of spatial detail desired. In water depths ranging from perhaps 50 to 200 ft,* a spatial step of 100-300 ft will probably suffice. With water currents of perhaps 1-3 fps, a 20 × 20 grid should be sufficient to result in the majority of the material being deposited on the grid. Quite often the user may wish to change the horizontal grid after a few preliminary runs. Water depths and the horizontal components of the ambient current must be known at each net point. Either of the options of velocity input illustrated in Figure 4 may be selected with the simplest case being velocities at a constant-depth disposal site. The ambient density profile at the deepest point in the disposal site must also be input and is assumed to be the same at each net point of the grid.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is found on page 3.

Characterization of dredged material

37. The dredged material is composed of solid fractions, a fluid component, and perhaps a conservative chemical constituent. For each solid fraction, its concentration by volume, specific gravity, fall velocity, void ratio after deposit on the bottom, and an indicator as to whether or not the fraction is cohesive must be entered. Proper material characterization is extremely important in obtaining realistic predictions from the models. To trace a conservative chemical constituent, its initial concentration and a background concentration must be given. In addition, the bulk density and aggregate void ratio of the dredged material after deposit on the bottom must be prescribed. If known, its moisture content, which is given as a multiple of the liquid limit of the particular type of material being disposed, can be entered to be used in expressions for coefficients developed by Bowers and Goldenblatt (1978).

Disposal operations data

38. For DIFID, information required includes the position of the barge or scow on the horizontal grid, the vessel dimensions, the velocity of the vessel, the unloaded draft of the disposal vessel, and the volume of material to be disposed. For DIFCD, the following data are required: the initial position of the discharge on the horizontal grid, the course and speed of the discharge source, the orientation and depth below the water surface of the discharge, the radius and flow rate of the discharge, and the total discharge time. Input data required by DIFHD to describe the disposal operation are similar to those for DIFCD with the addition of the number of bins opened at the same time as well as a representative length to increase the initial radius of the collapsing cloud on the bottom if two or more bins are opened simultaneously. For example, as illustrated in Figure 3, if pairs of bins are opened together, a good estimate of the initial radius of the collapsing cloud would be the computed radius of the jet formed from one bin plus one-half the distance between the two sets of doors.

Model coefficients

39. There are 13 coefficients in DIFID, 15 in DIFCD, and 14 in DIFHD that require input values if the user does not wish to use default values. In DIFID, ALPHAØ is the entrainment coefficient for a turbulent thermal determined experimentally by Koh and Chang (1973). ALPHAC is the coefficient for entrainment due to cloud collapse given by Koh and Chang (1973). BETA is the

settling coefficient given by Koh and Chang (1973). The default value is expected to be good for low solids concentrations. GAMA is a coefficient introduced by Koh and Chang (1973) to simulate the effect of density gradient differences on cloud collapse. The default value is based on an educated guess by Koh and Chang (1973). CD is the drag coefficient for a sphere in the range of Reynolds numbers expected. CD3 is the drag coefficient for a spheroidal wedge in the range of Reynolds numbers expected. Similarly, CD4 is the drag coefficient for a circular plate normal to the flow. CM is the apparent mass coefficient. The default values for the remaining coefficients CDRAG, CFRIC, and FRICTN were presented by Koh and Chang (1973) based on educated guess. CDRAG is the drag coefficient for an elliptic cylinder edge-on to the flow. CFRIC is a skin friction coefficient and FRICTN is a bottom friction coefficient. ALAMDA is a dissipation parameter used in the four-thirds law for horizontal diffusion. Based upon results presented by Brandsma and Divoky (1976), its value ranges from 0.005 to 0.00015 $ft^{2/3}$/sec, with the higher values more appropriate for estuarine environments. AKYØ is the vertical diffusion coefficient in a well-mixed water body. Kent and Pritchard (1959) gave

$$\mathrm{AKY\emptyset} = 8.6 \times 10^{-3} \frac{Uz^2(H - z)^2}{H^3} \tag{11}$$

where

U = mean horizontal velocity

z = depth of the point of interest

H = bottom depth.

For a depth of 50 ft and a mean velocity of 2.0 fps, a value of 0.05 is determined at middepth.

40. In DIFCD, ALPHA1 is the entrainment coefficient for a momentum jet. ALPHA2 is the entrainment coefficient for a 2-D thermal. ALPHA3 is the entrainment coefficient for a convecting thermal. The default values for ALPHA1, ALPHA2, and ALPHA3 were based upon work by Abraham (1970). ALPHA4 is a coefficient suggested by Koh and Chang (1973) for entrainment due to collapse. BETA and GAMA are as discussed in the previous paragraph. CD is the drag coefficient for a 2-D cylinder in crossflow in the range of Reynolds numbers expected. CD3 is the drag coefficient for a 2-D wedge. CD4 is the drag coefficient for a 2-D plate normal to the flow. CM, CDRAG, CFRIC, FRICTN,

ALAMDA, and AKYØ are coefficients that are the same as discussed in the preceding paragraph. Coefficients required in DIFHD are composed of coefficients from DIFCD and DIFID.

41. Default values of these coefficients are contained in the computer codes, and their values are listed in the input data lists presented in Appendices D, E, and F. However, as noted, the user may specify other values. Computer experimentation such as that presented by Johnson and Holliday (1978) has shown that model results appear to be fairly insensitive to many of the coefficients. The most important coefficients in the instantaneous dump model DIFID appear to be ALPHAØ, CD, CDRAG, FRICTN, and AKYØ. Each is briefly described in Appendix D. The most important coefficients in the continuous discharge model DIFCD appear to be ALPHA1, CD, CDRAG, FRICTN, and AKYØ. Each is briefly described in Appendix E. The most important coefficients in DIFHD are those from the jet convection phase of DIFCD, i.e., ALPHA1 and CD and those from the collapse and transport-diffusion phases of DIFID, i.e., CDRAG, FRICTN, and AKYØ.

42. If the user has no data to calibrate the models, it is suggested that the calibration efforts presented by Johnson and Holliday (1978) and Adamec et al. (1987) be studied. Figures 5 and 6 illustrate that a significant difference results in the computed bottom spread from a hopper dredge disposal operation in Lake Ontario depending upon the values of coefficients specified. It should be remembered that the results presented are from earlier versions of the models; thus, particular values of the coefficients listed may no longer be applicable. Figure 7 presents results from the more recent calibration effort at the Duwamish site using the following variables:

- a. t_R = Recorded time required for bottom encounter.
- b. t_c = Computed time required for bottom encounter.
- c. V_R = Recorded velocity of bottom surge at 150 ft downstream of the dump point.
- d. V_c = Computed velocity of leading edge of bottom collapsing cloud at 150 ft downstream of the dump point.
- e. C_R = Recorded concentration of suspended sediment at 3 ft off the bottom at 300 ft downstream of the dump point.
- f. C_c = Computed concentration of suspended sediment 3 ft off the bottom at 300 ft downstream of the dump point.

It is suggested that a sensitivity analysis involving the more important

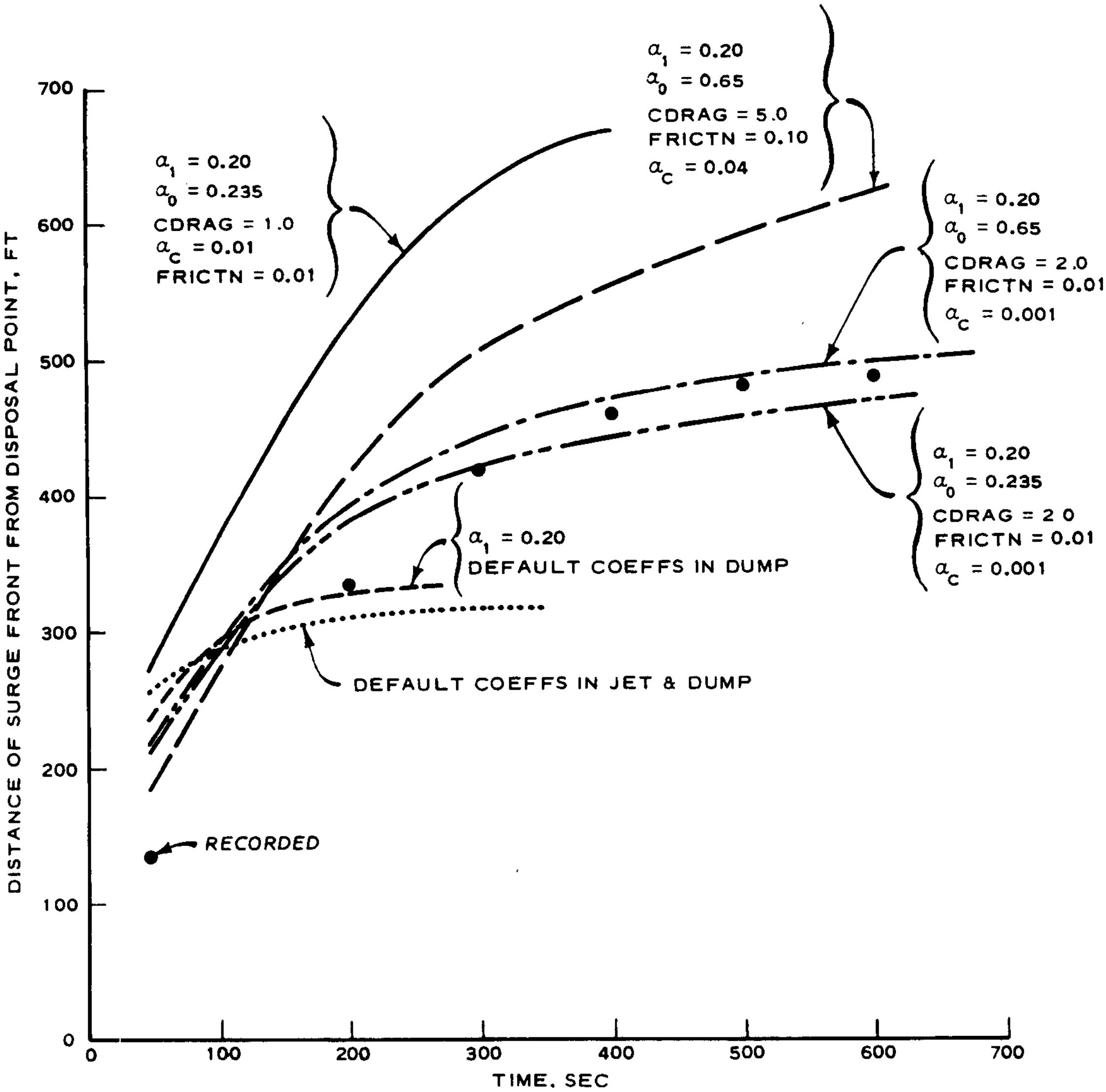

Figure 5. Surge spread versus time after disposal at the Lake Ontario 58-ft site (taken from Johnson and Holliday 1978)

coefficients be conducted for each new application of the models. Experimental work conducted by Bowers and Goldenblatt (1978) has been incorporated into DIFID in which the descent entrainment and drag coefficients as well as the added mass coefficient are related to the moisture content of the disposed material.

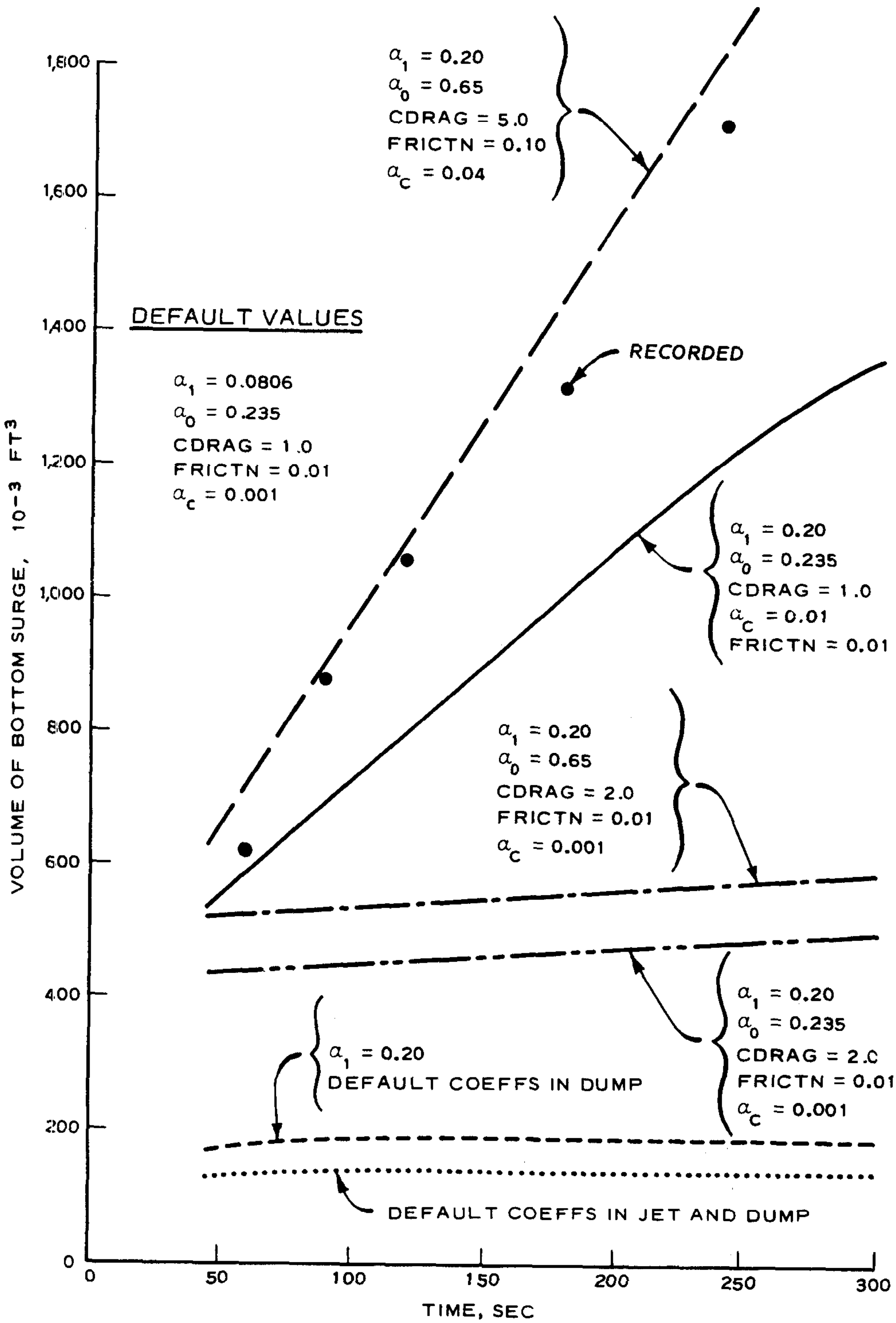

Figure 6. Surge volume versus time after disposal at the Lake Ontario 58-ft site (taken from Johnson and Holliday 1978)

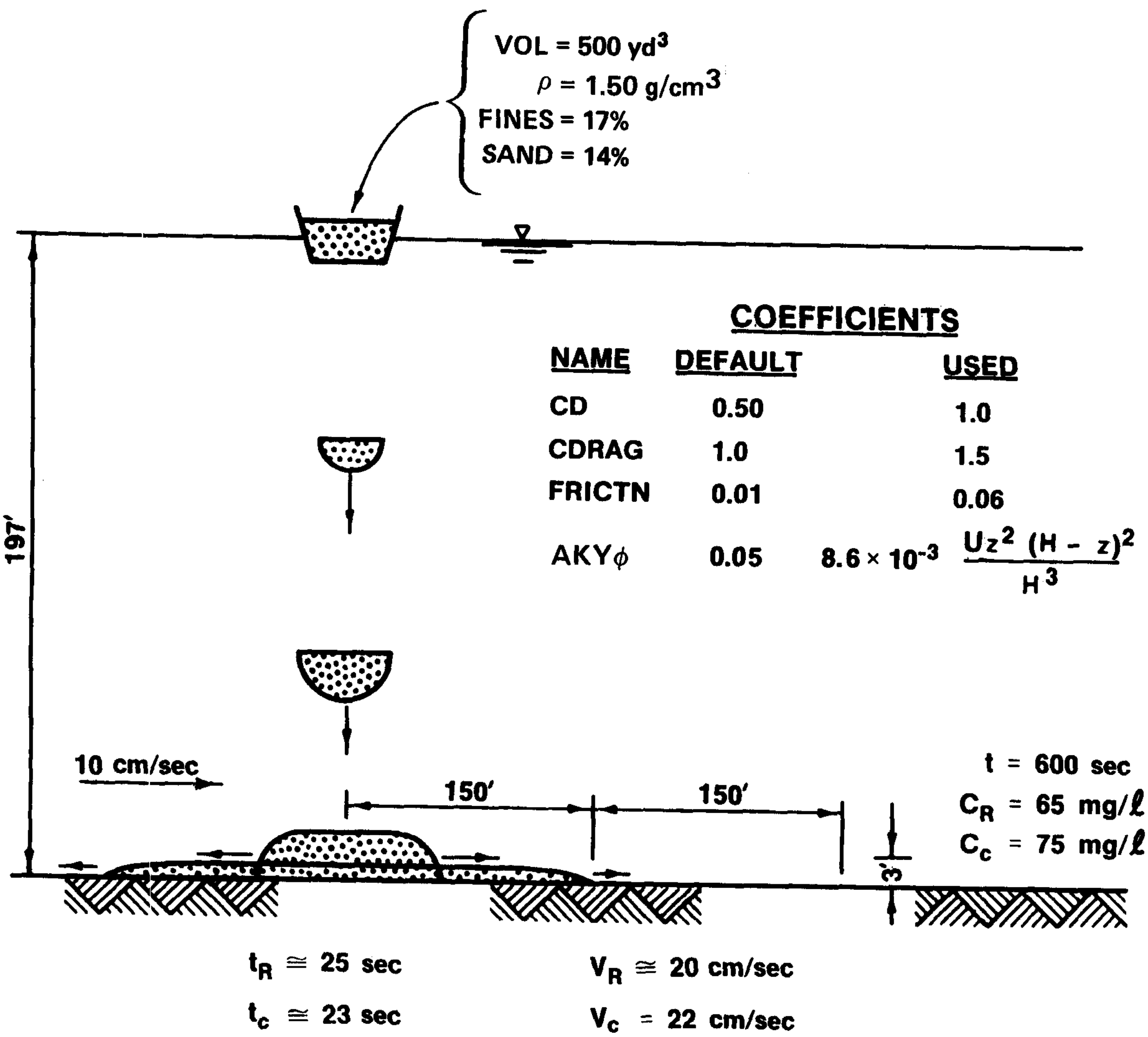

Figure 7. Results from recent calibration of DIFID at the Duwamish disposal site (from Johnson, Trawle, and Adamec, in preparation)

PART III: SUMMARY

43. Three computer models for predicting the short-term physical fate of dredged material disposed in open water have been presented. DIFID should be applied when the disposal operation is essentially instantaneous, whereas DIFCD is applicable to continuous disposal operations, e.g., pipeline disposal. DIFHD has been developed for application to dredged material disposal from a stationary hopper dredge in which two or more bins discharge material simultaneously. Theoretical aspects along with uses and limitations of the models have been discussed. Example applications of the models at a constant-depth site presented in Appendices A, B, and C serve to illustrate that very little input data are required for such applications. An inspection of the example data setups along with the formatted list of input cards presented in Appendices D, E, and F for DIFID, DIFCD, and DIFHD, respectively, should make application of the models relatively straightforward.

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APPENDIX A: EXAMPLE APPLICATION OF DIFID

1. To demonstrate the application of the instantaneous dump model DIFID, a 1,000-yd^3 disposal from a split hull barge at a constant-depth disposal site is modeled.

Input Data

Operations information

2. The total volume of the dredged material is 1,000 yd^3 and is contained in a barge 100 ft long and 50 ft wide. The barge is stationary and is located 1,000 ft from the top of a 15 × 15 grid and 1,500 ft from the left side of the grid. The grid spacing (Δx) is 200 ft. The unloaded draft of the barge is taken to be 5.0 ft with the time required to empty the barge taken as 5.0 sec. The total simulation time is arbitrarily taken to be 900 sec for demonstration purposes. The grid is positioned around the disposal point so that the collapse phase is contained completely within the grid. The size of the grid is determined so that suspended material will be contained within the grid for the desired simulation time. The transport-diffusion time-step is selected to be 100 sec. This value is selected so that a small cloud does not travel more than one Δx during the time-step. This will be true since the clouds are near the bottom and thus are advected by a low velocity.

Dredged material information

3. The dredged material is composed of a sand and a silty clay solid fraction. The sand volumetric concentration is 0.1395 ft^3/ft^3 and the silty clay volumetric concentration is 0.1705 ft^3/ft^3. The remaining 0.69 ft^3/ft^3 is composed of water. The settling velocity of the sand is taken to be 0.07 fps, whereas the silty clay fraction is treated as a cohesive fraction with the settling velocity computed from Equation 9 (main text). With these solids concentrations, the average bulk density of the material in the barge is 1.51 g/cc. Following deposition on the bottom, a void ratio of 4.0 is specified for the silty clay fraction, whereas a void ratio of 0.8 is specified for the sand. Therefore, the overall void ratio of the aggregate is 2.26. An ammonia concentration of 100 mg/ℓ is specified with the ambient background concentration being 0.0.

Disposal site information

4. The total water depth is 100 ft and no bottom slope exists. The ambient water current is 2.0 fps directed from the bottom of the grid toward the top over the top 40 ft of the water column. The current then reverses direction over the next 20 ft to become 2.0 fps directed from the top of the grid toward the bottom at 60 ft below the surface. A linear decrease to a value of zero at the bottom follows. This profile is illustrated in Figure A1.

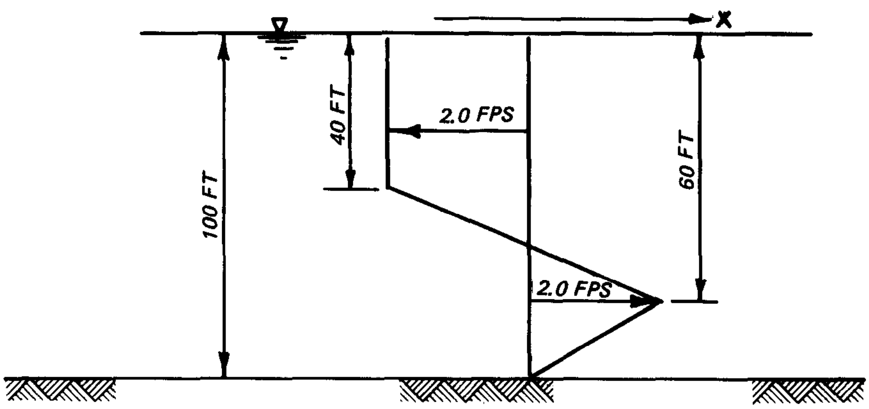

Figure A1. Ambient water current profile

5. The ambient density profile is taken as illustrated in Figure A2.

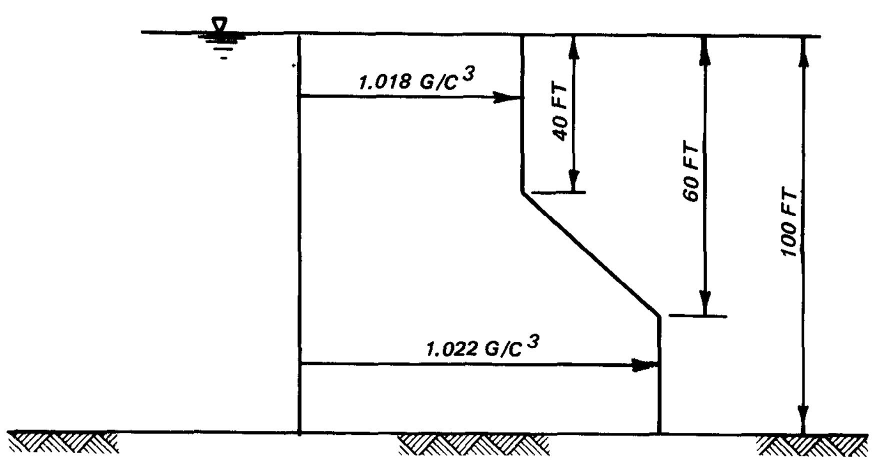

Figure A2. Ambient density profile

Coefficients

6. Default coefficients are prescribed for all coefficients except the bottom friction coefficient, which is taken to be 0.03.

7. The input data file required to model this disposal operation is

presented in Table A1 and is the response to the input requirements presented in Appendix D.

Model Results

8. A portion of the output from all computational phases from DIFID for the example problem is presented in Table A2. The output can be grouped into four categories. The first is an echo of much of the input data, and the next two are time-histories of the descent and collapse phases. The final group of output is a time-history of the suspended sediment as well as the conservative constituent concentrations and bottom deposition on the horizontal grid for each solids fraction. Since the suspended sediment is expected to be concentrated near the bottom, output has been requested at two vertical locations, namely, 1 and 2 ft from the bottom. All output is self-explanatory except for perhaps the computational indicators before both the descent and collapse phases and information concerning small clouds.

Computational indicators

9. Five trials with a new value being used each time for the integration step DT are allowed in the descent computations. The value of NTRIAL gives the trial number. A counter called ISTEP indicates the number of integration steps within each trial. At the end of each integration step, various checks are made to determine if the descent phase has been successfully computed or if a new trial with a new integration step is required. If the sum of the depth of the cloud centroid and three-eighths of the cloud radius is greater than the water depth, the variable labeled IPLUNG is changed from its default value of 0 to 1. This signifies that the bottom has been encountered. If a neutrally buoyant position is reached in the water column, the variable labeled NUTRL is changed from its default value of 0 to 1. If either IPLUNG or NUTRL attains a value of 1 and the value of ISTEP lies between 100 and 200, the descent phase has been successfully computed. If these conditions are not met after five trials, the model run terminates.

10. Five trials, with a new integration step DT for each trial, are also allowed in the collapse computations. Once again, the counter called ISTEP indicates the number of integration steps during each trial. If the bottom was not encountered in the descent phase but is then encountered after collapse in the water column is initiated, the variable labeled IPLUNG is set

to a value of 2. If IPLUNG = 2 and the number of integration steps lies between 100 and 200, collapse continues on the bottom. If while the cloud is collapsing on the bottom, the bed reaction force becomes negative, the cloud leaves the bottom and IPLUNG is set to 4. In addition, the value of ISTEP when this happens is assigned to the variable ILEAVE, which has a default value of 999. The variable labeled NUTRL is set to 3 when diffusive spreading becomes greater than the rate of collapse or if the cloud thickness becomes less than 1 percent of its initial value. In order for collapse computations to be successful, NUTRL must have a value of 3 and the number of collapse integration steps given by (ISTEP - IBED) must lie between 100 and 400. As in the descent phase, if these conditions are not met after five trials the model run terminates.

11. Before the presentation of output on the horizontal grid, information on the small sediment clouds is given. The time of cloud creation, its centroid location, the length of a side of a square with equivalent area to the circular cloud's area, the location of the top of the cloud, its thickness, its total mass, and its entrained mass are presented for each small cloud. The variables labeled NEWT and LAST give the values of ISTEP when the current and the previous small clouds were created, with LAST having a default value of 1.

Discussion

12. As can be seen from the computer printout, the disposal cloud strikes the bottom in 7.09 sec and grows from an initial radius of 23.44 ft to a final radius at bottom encounter of 47.5 ft. Collapse on the bottom then occurs with the collapse phase terminated at 58.44 sec after the disposal with the final bottom cloud having a diameter of 366.06 ft and a maximum thickness of 3.18 ft. After 900 sec, 158 ft^3 of silt remains in the water column with 4,441 ft^3 deposited on the bottom, whereas virtually all of the sand is on the bottom.

Table A1

Input Data for Example Application of DIFID

Card No.*	Variables	Values
1	ID	EXAMPLE APPLICATION OF DIFID
2	NMAX	15
	MMAX	15
	NS	2
3	KEY1	1
	KEY2	0
	KEY3	1
	JBFC	0
4	IPCN	1
	IPCL	1
	IPLT	0
5	NVERTS	2
6	YPOS(I)	99.0
		98.0
7	IDEP	1
	DEPC	100.0
	DX	200.0
9	XBARGE	1,000.0
	ZBARGE	1,500.0
	SLOPEX	0.0
	SLOPEZ	0.0
	XHOLE	0.0
	ZHOLE	0.0
	DHOLE	0.0
10	NROA	4
11	Y(I)	0.0
		40.0
		60.0
		100.0

(Continued)

* As numbered and described in Appendix D.

(Sheet 1 of 3)

Table A1 (Continued)

Card No.	Variables	Values
12	ROA(I)	1.018
		1.018
		1.022
		1.022
13	IFORM	3
14	DU1	40.0
	DU2	60.0
	UU1	-2.0
	UU2	2.0
	DW1	40.0
	DW2	60.0
	WW1	0.0
	WW2	0.0
15	TDUMP	0.0
	TSTOP	900.0
	DTL	100.0
16	VOLM	1,000.0
	DREL2	5.0
	CU	0.0
	CW	0.0
	TREL	5.0
17	ROO	1.51
	BVOID	2.26
	AMLL	0.0
18	BARGL	100.0
	BARGW	50.0
19	PARAM	SAND
	ROAS	2.60
	CS	0.1395
	VFALL	0.07
	VOIDS	0.8
	ICOHES	0
19	PARAM	SILT-CLAY
	ROAS	2.60
	CS	0.1705
	VFALL	0.02
	VOIDS	4.0
	ICOHES	1

(Continued)

(Sheet 2 of 3)

Table A1 (Concluded)

Card No.	Variables	Values
20	PARAM	AMMONIA
	CINIT	100.0
	CBACK	0.0
21	ALPHAØ	0.235
	BETA	0.0
	CM	1.0
	CD	0.50
22	GAMA	0.25
	CDRAG	1.0
	CFRIC	0.01
	CD3	0.10
	CD4	1.0
	ALPHAC	0.001
	FRICTN	0.03
23	ALAMDA	0.005
	AKYØ	0.05

(Sheet 3 of 3)

Table A2

Selected Computer Printout

DIFID

```
FATE OF DREDGED MATERIAL FROM AN INSTANTANEOUSDUMP FROM A BARGE OR SCOW


 EXAMPLE APPLICATION OF DIFID


STORAGE ALLOCATION PARAMETERS FOLLOW...
NMAX MMAX   NS
 15   15     2


EXECUTION PARAMETERS FOLLOW...
KEY1  KEY2  KEY3  IPCN  IPCL  IPLT  JBFC
  1     0     1     1     1     0     0


VERTICAL POSITIONS FOR OUTPUT FROM GAUSSIAN CLOUDS
   99.00   98.00

NUMBER OF LONG TERM GRID POINTS IN Z-DIRECTION(NMAX) =  15
NUMBER OF LONG TERM GRID POINTS IN X-DIRECTION(MMAX) =  15

GRID SPACING (DX) =    200.00000
1      DEPTH GRID FOLLOWS...

 M N= 1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
 1  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
 2  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
 3  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
 4  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
 5  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
 6  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
 7  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
 8  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
 9  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
10  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
11  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
12  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
13  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
14  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
15  100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
1      CODED ARRAY FOLLOWS...
```

(Continued)

(Sheet 1 of 12)

Table A2 (Continued)

```
                ---AMBIENT CONDITIONS---

     DEPTH (FT)        0.          40.00       60.00       100.0
AMBIENT
DENSITY (GM/CC)        1.018       1.018       1.022       1.022


INTERPOLATED DEPTH AT DUMP COORDINATES, H =    100.0     FT.
--------------------------------------------------------------------


TWO VELOCITY PROFILES SPECIFIED IN X AND Z DIRECTIONS FOR --QUICK LOOKS--
DEPTH ASSUMED CONSTANT AND VELOCITIES CONSIDERED STEADY IN TIME
VELOCITY PROFILE PARAMETERS FOLLOW...
DU1 =    40.0     DU2 =    99.0     UU1 =   -2.00     UU2 =    2.00
DW1 =    40.0     DW2 =    99.0     WW1 =   0.        WW2 =   0.


TIME PARAMETERS FOLLOW...
TIME OF DUMP =         .00 SECONDS AFTER START OF TIDAL CYCLE
DURATION OF SIMULATION =     900.00 SECONDS AFTER DUMP
LONG TERM TIME STEP (DTL) =     100.00 SECONDS

1

DISCHARGE PARAMETERS...
INITIAL RADIUS OF CLOUD, RB =    23.44039
INITIAL DEPTH OF CLOUD CENTROID, DREL =    17.87
INITIAL CLOUD VELOCITIES...CU(1) =   0.         CV(1) =    1.631      CW(1) =   0.

BULK PARAMETERS...
DENSITY, ROO =    1.510000
AGGREGATE VOIDS RATIO, BVOID =    2.260
MULTIPLE OF LIQUID LIMIT =   0.


THERE ARE  2 SOLIDS,  PARAMETERS FOLLOW.......

DESCRIPTION  DENSITY(GM/CC)  CONCENTRATION(CUFT/CUFT)  FALL VELOCITY(FT/SEC)   VOIDS RATIO

  SAND        2.600                .1395                   .7000E-01          .8000
  SILT-CY     2.600                .1705                   .2000E-01          4.000
 FLUID        1.020                .6900                  0.
```

(Continued)

1 CONVECTIVE DESCENT

COMPUTATIONAL INDICATORS FOLLOW...

NTRIAL	DT	IPLUNG	NUTRL	ISTEP
1	.24608183E-01	1	0	288
2	.47247711E-01	1	0	151

IPLUNG = 0-INITIALLY
1-IF BOTTOM ENCOUNTERED IN CONV DESCENT
NUTRL = 0-INITIALLY
1-IF NEUTRALLY BUOYANT POSITION REACHED IN CONV DESCENT

IF NTRIAL EQ 5 AND NUTRL AND IPLUNG EQ 0 , PROGRAM TERMINATES

X AND Z ARE MEASURED W/R TO BARGE POSITION

TIME	X	Y	Z	U	V	W	DEN-DIF	RADIUS	TRAC CONC	SOLID-VOL.	CONCENTRATION
.00	.00	17.87	.00	.00	1.631	.00	.4920E+00	23.44	100.00	.3763E+04	.1395E+00
										.4599E+04	.1705E+00
.09	.00	18.07	.00	-.04	2.563	.00	.4775E+00	23.68	97.05	.3763E+04	.1354E+00
										.4599E+04	.1655E+00
.19	-.01	18.35	.00	-.09	3.437	.00	.4607E+00	23.96	93.64	.3763E+04	.1306E+00
										.4599E+04	.1597E+00
.28	-.02	18.71	.00	-.15	4.243	.00	.4421E+00	24.29	89.85	.3763E+04	.1253E+00
										.4599E+04	.1532E+00
.38	-.04	19.15	.00	-.22	4.977	.00	.4223E+00	24.66	85.84	.3763E+04	.1197E+00
										.4599E+04	.1463E+00
.47	-.06	19.65	.00	-.28	5.637	.00	.4020E+00	25.07	81.71	.3763E+04	.1140E+00
										.4599E+04	.1393E+00
.57	-.09	20.21	.00	-.35	6.225	.00	.3818E+00	25.51	77.60	.3763E+04	.1083E+00
										.4599E+04	.1323E+00
.66	-.13	20.83	.00	-.42	6.743	.00	.3621E+00	25.96	73.59	.3763E+04	.1027E+00
										.4599E+04	.1255E+00
.76	-.17	21.48	.00	-.49	7.197	.00	.3431E+00	26.43	69.74	.3763E+04	.9729E-01
										.4599E+04	.1189E+00
.85	-.22	22.18	.00	-.55	7.593	.00	.3251E+00	26.91	66.09	.3763E+04	.9219E-01
										.4599E+04	.1127E+00
.94	-.27	22.92	.00	-.61	7.937	.00	.3082E+00	27.39	62.65	.3763E+04	.8740E-01
										.4599E+04	.1068E+00
1.04	-.33	23.68	.00	-.68	8.236	.00	.2925E+00	27.88	59.44	.3763E+04	.8292E-01
										.4599E+04	.1014E+00
1.13	-.40	24.47	.00	-.73	8.495	.00	.2778E+00	28.36	56.46	.3763E+04	.7876E-01
										.4599E+04	.9626E-01
1.23	-.47	25.29	.00	-.79	8.719	.00	.2641E+00	28.84	53.69	.3763E+04	.7490E-01
										.4599E+04	.9154E-01
1.32	-.55	26.12	.00	-.84	8.913	.00	.2515E+00	29.32	51.12	.3763E+04	.7132E-01
										.4599E+04	.8717E-01
1.42	-.63	26.97	.00	-.89	9.081	.00	.2398E+00	29.78	48.75	.3763E+04	.6900E-01
										.4599E+04	.8318E-01
1.51	-.72	27.84	.00	-.93	9.226	.00	.2290E+00	30.24	46.55	.3763E+04	.6494E-01
										.4599E+04	.7937E-01
1.61	-.81	28.71	.00	-.98	9.352	.00	.2190E+00	30.70	44.52	.3763E+04	.6210E-01
										.4599E+04	.7590E-01
1.70	-.90	29.60	.00	-1.02	9.460	.00	.2097E+00	31.15	42.63	.3763E+04	.5947E-01

(Continued)

6.61	-7.07	78.09	.00	-.93	9.578	.00	.6091E-01	46.44	12.86	.3763E+04 .4599E+04	.1794E-01 .2193E-01
6.71	-7.15	78.99	.00	-.90	9.556	.00	.6007E-01	46.65	12.69	.3763E+04 .4599E+04	.1770E-01 .2163E-01
6.80	-7.24	79.89	.00	-.88	9.534	.00	.5924E-01	46.87	12.51	.3763E+04 .4599E+04	.1745E-01 .2133E-01
6.90	-7.32	80.79	.00	-.85	9.510	.00	.5844E-01	47.08	12.34	.3763E+04 .4599E+04	.1722E-01 .2104E-01
6.99	-7.40	81.69	.00	-.83	9.487	.00	.5765E-01	47.29	12.17	.3763E+04 .4599E+04	.1698E-01 .2076E-01
7.09	-7.47	82.59	.00	-.80	9.462	.00	.5688E-01	47.51	12.01	.3763E+04 .4599E+04	.1676E-01 .2048E-01

1 COLLAPSE PHASE OF CLOUD

COMPUTATIONAL INDICATORS...

NTRIAL	DT	IPLUNG	NUTRL	ISTEP	IBED	ILEAVE
1	.4725E-01	1	0	598	151	999
2	.8448E-01	1	0	598	151	999
3	.1510	1	3	491	151	999

```
IPLUNG = 0-INITIALLY
         1-IF BOTTOM ENCOUNTERED IN CONV DESCENT
         2-IF BOTTOM ENCOUNTERED IN COLAPS
         4-IF CLOUD RISES FROM BOTTOM
NUTRL = 0-INITIALLY
        3-IF DIFFUSION GT DYNAMIC SPREADING
```

IF NTRIAL EQ 5 AND NUTRL NE 3 , PROGRAM TERMINATES

X AND Z MEASURED FROM BARGE POSITION

TIME	X	Y	Z	U	V	W	DEN-DIF	YA	XB	ZC	TRAC CONC	SOLID-VOL	CONCENTRATION
7.09	-7.47	82.59	.00	-.80	9.46	.00	.5688E-01	47.51	95.02	95.02	.1201E+02	.3763E+04 .4599E+04	.1676E-01 .2048E-01
7.84	-7.89	86.07	.00	-.46	5.32	.00	.5646E-01	37.14	107.78	107.78	.1194E+02	.3756E+04 .4593E+04	.1663E-01 .2034E-01
8.60	-8.20	89.01	.00	-.38	3.80	.00	.5621E-01	29.32	121.45	121.45	.1191E+02	.3747E+04 .4586E+04	.1655E-01 .2025E-01
9.35	-8.46	91.06	.00	-.30	2.66	.00	.5600E-01	23.84	134.76	134.76	.1190E+02	.3736E+04 .4577E+04	.1648E-01 .2019E-01
10.11	-8.66	92.51	.00	-.24	1.89	.00	.5579E-01	19.97	147.27	147.27	.1189E+02	.3722E+04 .4565E+04	.1641E-01 .2013E-01
10.86	-8.82	93.56	.00	-.18	1.39	.00	.5557E-01	17.17	158.88	158.88	.1189E+02	.3706E+04 .4552E+04	.1633E-01 .2006E-01
11.62	-8.94	94.35	.00	-.13	1.05	.00	.5533E-01	15.07	169.59	169.59	.1189E+02	.3688E+04 .4537E+04	.1625E-01 .1999E-01
12.37	-9.02	94.95	.00	-.09	.82	.00	.5506E-01	13.46	179.47	179.47	.1188E+02	.3667E+04 .4520E+04	.1616E-01 .1991E-01
13.13	-9.07	95.43	.00	-.04	.65	.00	.5477E-01	12.19	188.60	188.60	.1188E+02	.3644E+04 .4501E+04	.1606E-01 .1983E-01
13.88	-9.08	95.81	.00	.00	.53	.00	.5445E-01	11.17	197.05	197.05	.1188E+02	.3620E+04 .4481E+04	.1595E-01 .1974E-01
14.64	-9.08	96.13	.00	.00	.44	.00	.5411E-01	10.33	204.90	204.90	.1188E+02	.3593E+04 .4459E+04	.1583E-01 .1964E-01
15.39	-9.08	96.39	.00	.00	.37	.00	.5375E-01	9.63	212.20	212.20	.1188E+02	.3566E+04 .4436E+04	.1571E-01 .1954E-01

(Continued)

(Sheet 4 of 12)

56.18	-9.05	98.78	.00	.00	.01	.00	.2421E-01	3.25	362.28	362.28	.1209E+02	.1365E+04 .2328E+04	.8114E-02 .1043E-01
56.93	-9.05	98.79	.00	.00	.01	.00	.2372E-01	3.22	363.57	363.57	.1209E+02	.1338E+04 .2290E+04	.5967E-02 .1026E-01
57.69	-9.05	98.80	.00	.00	.01	.00	.2323E-01	3.20	364.83	364.83	.1209E+02	.1299E+04 .2252E+04	.5824E-02 .1010E-01
58.44	-9.05	98.81	.00	.00	.01	.00	.2274E-01	3.18	366.06	366.06	.1210E+02	.1267E+04 .2215E+04	.5682E-02 .9931E-02

FALL VELOCITY OF SILT-CY COMPUTED TO BE .047000

1

BEGIN LONG TERM SIMULATION OF FATE OF SAND

NEW CLOUD CREATED, NTCLD = 1

T(SEC)	TX	TZ	TSIDE	TOP	TTHK	TMASS	TEMAS	NEWT	LAST
14.04	990.9	1500.	176.1	99.02	.9825	148.3	0.	197	1

NEW CLOUD CREATED, NTCLD = 1

T(SEC)	TX	TZ	TSIDE	TOP	TTHK	TMASS	TEMAS	NEWT	LAST
21.44	990.9	1500.	227.6	99.48	.5181	330.4	0.	246	197

NEW CLOUD CREATED, NTCLD = 1

T(SEC)	TX	TZ	TSIDE	TOP	TTHK	TMASS	TEMAS	NEWT	LAST
28.84	990.9	1500.	259.1	99.48	.5181	420.1	0.	295	246

NEW CLOUD CREATED, NTCLD = 1

T(SEC)	TX	TZ	TSIDE	TOP	TTHK	TMASS	TEMAS	NEWT	LAST
36.24	990.9	1500.	281.5	99.48	.5181	444.3	0.	344	295

NEW CLOUD CREATED, NTCLD = 1

T(SEC)	TX	TZ	TSIDE	TOP	TTHK	TMASS	TEMAS	NEWT	LAST
43.64	990.9	1500.	298.8	99.48	.5181	427.8	0.	393	344

NEW CLOUD CREATED, NTCLD = 1

T(SEC)	TX	TZ	TSIDE	TOP	TTHK	TMASS	TEMAS	NEWT	LAST
51.04	990.9	1500.	312.8	99.48	.5181	387.9	0.	442	393

NEW CLOUD CREATED, NTCLD = 1

T(SEC)	TX	TZ	TSIDE	TOP	TTHK	TMASS	TEMAS	NEWT	LAST
58.44	991.0	1500.	324.4	96.30	3.696	1604.	0.	491	442

(Continued)

(Sheet 5 of 12)

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     SUMMARY OF  SAND    DISTRIBUTIONS AFTER     100.00 SEC.

     TOTAL SUSPENDED MATERIAL (CUFT) =     341.72
     TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     3421.2


     SUMMARY OF  SAND    DISTRIBUTIONS AFTER     200.00 SEC.

     TOTAL SUSPENDED MATERIAL (CUFT) =     11.049
     TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     3751.9
1CONCENTRATIONS ABOVE BACKGROUND OF  SAND   (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD    200.00 SECONDS AFTER DUMP

              99.00 FT BELOW THE WATER SURFACE
 ...MULTIPLY DISPLAYED VALUES BY   .1000E-05    (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   .   +   +   .   0   0   0   00000

   5 0000   0   0   . .01 .37 .37 .01   .   0   0   00000

   6 0000   0   0   + .18 4.3 4.3 .18   +   0   0   00000

   7 0000   0   0   + .08 2.0 2.0 .08   +   0   0   00000

   8 0000   0   0   .   + .04 .04   +   .   0   0   00000

   9 0000   0   0   0   .   .   .   .   0   0   0   00000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000
1CONCENTRATIONS ABOVE BACKGROUND OF  SAND   (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD    200.00 SECONDS AFTER DUMP

              98.00 FT BELOW THE WATER SURFACE
 ...MULTIPLY DISPLAYED VALUES BY   .1000E-05    (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14
```

(Continued)

(Sheet 6 of 12)

Table A2 (Continued)

```
    SUMMARY OF  SAND    DISTRIBUTIONS AFTER     900.00 SEC.                BEGIN LONG TERM SIMULATION OF FATE OF  SILT-CY
                                                           ??
    TOTAL SUSPENDED MATERIAL (CUFT) =      .22156
    TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     3762.7
1BOTTOM ACCUMULATION OF  SAND    (CUFT/GRID SQUARE) ,     900.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   10.00          (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0 247  32   0   0   0   0   00000

   6 0000   0   0   0   0  40  40   0   0   0   0   00000

   7 0000   0   0   0   0 8.4 8.4   0   0   0   0   00000

   8 0000   0   0   0   + .16 .16   +   0   0   0   00000

   9 0000   0   0   0 .01 .04 .04 .01   0   0   0   00000

  10 0000   0   0   0 .01 .01 .01 .01   0   0   0   00000

  11 0000   0   0   0   +   +   +   +   0   0   0   00000

  12 0000   0   0   0   +   +   +   +   0   0   0   00000

  13 0000   0   0   0   +   +   +   +   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000000
1THICKNESS (FT) OF  SAND    ACCUMULATED ON BOTTOM,      900.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0 .11 .01   0   0   0   0   00000

   6 0000   0   0   0   0 .01 .01   0   0   0   0   00000

   7 0000   0   0   0   0   +   +   0   0   0   0   00000

   8 0000   0   0   0   .   .   .   .   0   0   0   00000

   9 0000   0   0   0   .   .   .   .   0   0   0   00000

  10 0000   0   0   0   .   .   .   .   0   0   0   00000

  11 0000   0   0   0   .   .   .   .   0   0   0   00000

  12 0000   0   0   0   .   .   .   .   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000000
1
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(Continued)

(Sheet 7 of 12)

Table A2 (Continued)

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SUMMARY OF  SILT-CY DISTRIBUTIONS AFTER     100.00 SEC.

TOTAL SUSPENDED MATERIAL (CUFT) =      1157.4
TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     3441.7



SUMMARY OF  SILT-CY DISTRIBUTIONS AFTER     200.00 SEC.

TOTAL SUSPENDED MATERIAL (CUFT) =      479.07
TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     4120.0
1CONCENTRATIONS ABOVE BACKGROUND OF  SILT-CY (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD    200.00 SECONDS AFTER DUMP

            99.00 FT BELOW THE WATER SURFACE
 ...MULTIPLY DISPLAYED VALUES BY   .1000E-03     (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

  2 000000000000000000000000000000000000000000000000000
  3 0000   0   0   0   0   0   0   0   0   0   0   00000
  4 0000   0   0   0   .   +   +   .   0   0   0   00000
  5 0000   0   0   .   + .12 .12   +   .   0   0   00000
  6 0000   0   0   + .05 1.3 1.3 .05   +   0   0   00000
  7 0000   0   0   . .02 .62 .62 .02   .   0   0   00000
  8 0000   0   0   0   + .01 .01   +   0   0   0   00000
  9 0000   0   0   0   0   .   .   0   0   0   0   00000
 10 0000   0   0   0   0   0   0   0   0   0   0   00000
 11 0000   0   0   0   0   0   0   0   0   0   0   00000
 12 0000   0   0   0   0   0   0   0   0   0   0   00000
 13 0000   0   0   0   0   0   0   0   0   0   0   00000
 14 000000000000000000000000000000000000000000000000000
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(Continued)

(Sheet 8 of 12)

Table A2 (Continued)

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    SUMMARY OF  SILT-CY DISTRIBUTIONS AFTER     900.00 SEC.

    TOTAL SUSPENDED MATERIAL (CUFT) =      158.07
    TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =      4441.0
1BOTTOM ACCUMULATION OF  SILT-CY (CUFT/GRID SQUARE) ,     900.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   10.00        (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

   2 00000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0 236  36   0   0   0   0   00000

   6 0000   0   0   0   0  56  56   0   0   0   0   00000

   7 0000   0   0   0 .28  21  21 .28   0   0   0   00000

   8 0000   0   0   0 .49 4.6 4.6 .49   0   0   0   00000

   9 0000   0   0   0 .49 1.7 1.7 .49   0   0   0   00000

  10 0000   0   0   0 .49 .49 .49 .49   0   0   0   00000

  11 0000   0   0   0 .06 .06 .06 .06   0   0   0   00000

  12 0000   0   0   0   +   +   +   +   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 00000000000000000000000000000000000000000000000000
1THICKNESS (FT) OF  SILT-CY ACCUMULATED ON BOTTOM,     900.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000        (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

   2 00000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0 .29 .04   0   0   0   0   00000

   6 0000   0   0   0   0 .06 .06   0   0   0   0   00000

   7 0000   0   0   0   + .02 .02   +   0   0   0   00000

   8 0000   0   0   0   +   +   +   +   0   0   0   00000

   9 0000   0   0   0   +   +   +   +   0   0   0   00000

  10 0000   0   0   0   +   +   +   +   0   0   0   00000

  11 0000   0   0   0   .   .   .   .   0   0   0   00000

  12 0000   0   0   0   .   .   .   .   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 00000000000000000000000000000000000000000000000000
1
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(Continued)

(Sheet 9 of 12)

Table A2 (Continued)

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SUMMARY OF  AMMONIA DISTRIBUTIONS AFTER     100.00 SEC

TOTAL TRACER IN SOLUTION (MG) =       .76E+08


SUMMARY OF  AMMONIA DISTRIBUTIONS AFTER     200.00 SEC

TOTAL TRACER IN SOLUTION (MG) =       .76E+08
1CONCENTRATIONS ABOVE BACKGROUND OF  AMMONIA (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD    200.00 SECONDS AFTER DUMP

            99.00 FT BELOW THE WATER SURFACE
 ...MULTIPLY DISPLAYED VALUES BY   1.000        (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   .   +   +   .   0   0   0   00000

   5 0000   0   0   .   + .04 .04   +   .   0   0   00000

   6 0000   0   0   . .02 .49 .49 .02   .   0   0   00000

   7 0000   0   0   .   + .20 .20   +   .   0   0   00000

   8 0000   0   0   0   +   +   +   +   0   0   0   00000

   9 0000   0   0   0   0   .   .   0   0   0   0   00000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000000
```

(Continued)

Table A2 (Continued)

```
    SUMMARY OF  AMMONIA DISTRIBUTIONS AFTER     800.00 SEC

    TOTAL TRACER IN SOLUTION (MG) =        .76E+08
1CONCENTRATIONS ABOVE BACKGROUND OF  AMMONIA (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD    800.00 SECONDS AFTER DUMP

                99.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY   .1000E-01     (LEGEND... + = .LT. .01    . = .LT. .0001   0 = .LT. .000001)
 M N=  2    3    4    5    6    7    8    9   10   11   12   13   14

  2 00000000000000000000000000000000000000000000000000000

  3 0000   0    0    .    .    .    .    .    .    0    0    00000

  4 0000   0    .    +    +    +    +    +    +    .    0    00000

  5 0000   .    +    +  .04  .10  .10  .04    +    +    .    00000

  6 0000   +    +  .07  .39  .92  .92  .39  .07    +    +    .0000

  7 0000   +  .02  .27  1.5  3.5  3.5  1.5  .27  .02    +    .0000

  8 0000   +  .03  .45  2.4  5.8  5.8  2.4  .45  .03    +    .0000

  9 0000   +  .02  .31  1.7  4.0  4.0  1.7  .31  .02    +    .0000

 10 0000   +    +  .09  .51  1.2  1.2  .51  .09    +    +    .0000

 11 0000   .    +  .01  .06  .15  .15  .06  .01    +    .    00000

 12 0000   .    .    +    +    +    +    +    +    .    .    00000

 13 0000   0    .    .    .    +    +    .    .    .    0    00000

 14 00000000000000000000000000000000000000000000000000000
```

(Concluded)

(Sheet 11 of 12)

Table A2 (Concluded)

```
       FINAL DISTRIBUTIONS OF TOTAL SETTLED MATERIAL FOLLOW.....
1TOTAL ACCUMULATED SOLID VOLUME ON BOTTOM (CUFT/GRID SQR),      900.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY    10.00          (LEGEND... + = .LT. .01    . = .LT. .0001    0 = .LT. .000001)
  M N=  2    3    4    5    6    7    8    9   10   11   12   13   14

   2 0000000000000000000000000000000000000000000000000000

   3 0000    0    0    0    0    0    0    0    0    0    0   00000

   4 0000    0    0    0    0    0    0    0    0    0    0   00000

   5 0000    0    0    0    0  484   67    0    0    0    0   00000

   6 0000    0    0    0    0   96   96    0    0    0    0   00000

   7 0000    0    0    0  .28   30   30  .28    0    0    0   00000

   8 0000    0    0    0  .50  4.7  4.7  .50    0    0    0   00000

   9 0000    0    0    0  .50  1.8  1.8  .50    0    0    0   00000

  10 0000    0    0    0  .50  .50  .50  .50    0    0    0   00000

  11 0000    0    0    0  .06  .06  .06  .06    0    0    0   00000

  12 0000    0    0    0    +    +    +    +    0    0    0   00000

  13 0000    0    0    0    +    +    +    +    0    0    0   00000

  14 0000000000000000000000000000000000000000000000000000
1TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM,      900.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY    1.000          (LEGEND... + = .LT. .01    . = .LT. .0001    0 = .LT. .000001)
  M N=  2    3    4    5    6    7    8    9   10   11   12   13   14

   2 0000000000000000000000000000000000000000000000000000

   3 0000    0    0    0    0    0    0    0    0    0    0   00000

   4 0000    0    0    0    0    0    0    0    0    0    0   00000

   5 0000    0    0    0    0  .39  .05    0    0    0    0   00000

   6 0000    0    0    0    0  .07  .07    0    0    0    0   00000

   7 0000    0    0    0    +  .02  .02    +    0    0    0   00000

   8 0000    0    0    0    +    +    +    +    0    0    0   00000

   9 0000    0    0    0    +    +    +    +    0    0    0   00000

  10 0000    0    0    0    +    +    +    +    0    0    0   00000

  11 0000    0    0    0    .    .    .    .    0    0    0   00000

  12 0000    0    0    0    .    .    .    .    0    0    0   00000

  13 0000    0    0    0    0    0    0    0    0    0    0   00000

  14 0000000000000000000000000000000000000000000000000000
```

(Sheet 12 of 12)

APPENDIX B: EXAMPLE APPLICATION OF DIFCD

1. To demonstrate the application of the continuous discharge model DIFCD, a pipeline disposal operation at a constant-depth disposal site is modeled.

Input Data

Operations information

2. The pipeline is 1.0 ft in diameter with a discharge rate of 5.0 fps. The total simulation time is 2,400 sec with a continuous discharge for the entire simulation period. These values will depend upon the particular disposal operation. A 15 × 15 grid with a grid spacing (Δx) of 200 ft is employed. The end of the pipe is located 1,500 ft from the top of the grid and 800 ft from the left side of the grid. The end of the pipe is located 10 ft below the water surface at an angle of 90 deg with respect to the water surface. The grid is constructed so that suspended material will remain within the grid for the desired simulation period. The transport-diffusion time-step is taken to be 600 sec. This value must be greater than the time required for the completion of the collapse phase but less than the time required to transport a cloud one Δx .

Dredged material information

3. The dredged material possesses an average bulk density of 1.32 g/cc and is composed of two solid fractions, i.e., sand and silt. The concentration of each is 0.10 ft^3/ft^3 with the settling velocity of the sand taken to be 0.07 fps and that of the silt taken to be 0.02 fps. The aggregate void ratio is taken to be 1.9 with the void ratio of the silt taken as 3.0 and that of the sand as 0.8. An ammonia concentration of 100 mg/ℓ exists in the discharged material with the ambient concentration taken to be 0.0.

Disposal site information

4. The disposal site is a constant-depth site of 50 ft. The ambient water current is directed from the left of the grid toward the right with a magnitude of 0.5 fps over the upper 45 ft of the water column. The velocity then linearly decreases to 0.25 fps at 1 ft above the bottom and finally to zero at the bottom. This profile is illustrated in Figure B1.

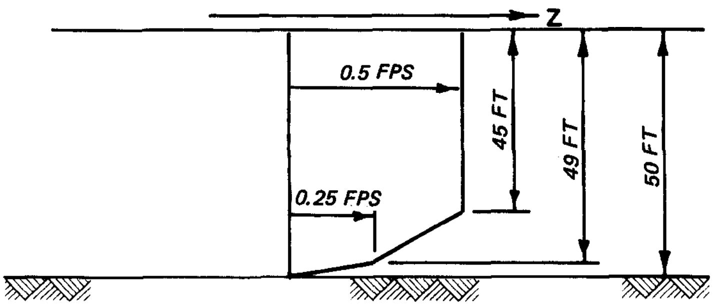

Figure B1. Ambient water current profile

The ambient density is assumed to vary linearly from 1.0 g/cc at the surface to 1.010 g/cc at the bottom.

Coefficients

5. Default values are selected for all coefficients.

6. The input data file required by DIFCD is presented in Table B1 and is the response to the input requirements presented in Appendix E.

Model Results

7. Output from DIFCD for the example problem, which consists of output from all computational phases (Table B2), is discussed in the following paragraphs. The output can be grouped into four categories. The first is an echo of much of the input data, with the next two being time-histories of the descent and collapse phases. The final group of output is a time-history of the suspended sediment as well as the conservative constituent concentrations and bottom deposition on the horizontal grid for each solids fraction. Since the suspended sediment is expected to be concentrated near the bottom, output has been requested at 1.0 ft from the bottom. All output is self-explanatory except for perhaps the computational indicators before both the descent and collapse phases and information concerning small clouds.

Computational indicators

8. Five trials, with a new value each trial for the integration step DS, are allowed in the descent computations. NTRIAL gives the value of the last trial. The counter ISTEP indicates the number of integration steps. At the end of each integration step, various checks are made to determine if the jet convection phase has been successfully computed or if a new trial with a new integration step is required. The current trial is reconsidered if a neutrally buoyant position is computed which results in NUTRL being changed

from its default value of 0 to 1, if the bottom has been encountered, or if ISTEP > 600. Bottom encounter occurs if any of the following three expressions are satisfied, which results in IPLUNG = 1.

$$CY(ISTEP) + 0.85 * BC(ISTEP)\ SIN\ \Theta_2 \geq H \qquad (B1)$$

$$CY(ISTEP) + DS \times COS\ \Theta_2 \geq H \qquad (B2)$$

$$CY(ISTEP) + 0.75 * BC(ISTEP) \geq H\ \ IF\ \ \Theta_2 < 30\ deg \qquad (B3)$$

where

CY = vertical position of jet center line

ISTEP = number of integration steps

BC = jet radius

Θ_2 = angle between vertical and jet center line

H = water depth

DS = spatial integration step

Jet convection computations are considered complete if either NUTRL = 1 or IPLUNG = 1 and NTRIAL $\leq$ 5 and the number of integration steps ISTEP lies between 100 and 200. If a new trial is required, the jet computations are reinitiated but with the integration step set to be the old step multiplied by (DINCR * ISTEP/140) where DINCR can be input by the user. If after five trials a successful completion has not been realized, the program terminates.

9. Five trials with a new integration step each trial are also allowed in the collapse computations. At the end of each integration step, various checks are made to determine if the integration step counter ISTEP is to be incremented with the computations proceeding or if NTRIAL should be incremented with the computations starting over from the end of the jet convection. If diffusive spreading is greater than dynamic spreading, the variable labeled NUTRL takes on a value of 3. If the number of collapse integration steps lies between 100 and 400 and NUTRL = 3, collapse computations have been successfully completed. However if NUTRL = 3 and ISTEP > 599, a new trial is attempted. If NTRIAL > 5, the program terminates. As previously noted, if the bottom is encountered during the jet convection phase, the variable labeled IPLUNG is set to 1. However, if the jet convection phase terminates

in the water column and then the bottom is encountered during the collapse phase, IPLUNG is set to 2.

10. Before the presentation of output on the horizontal grid, information on the small sediment clouds is given. The time of cloud creation, its centroid location, the length of a side of a square with equivalent area to the circular cloud's area, the location of the top of the cloud, its thickness, its total mass, and its entrained mass are presented for each cloud. The variables labeled NEWT and LAST give the values of ISTEP when the current and the previous small clouds were created, with LAST having a default value of 1.

Discussion

11. As indicated in the computer printout, the momentum jet strikes the bottom after 10.29 sec with a radius of 4.496 ft. Collapse on the bottom terminates after 29.66 sec. After 2,400 sec, 97 percent of the sand and silt is deposited on the bottom, and the maximum ammonia concentration at 1.0 ft above the bottom is 0.30 mg/ℓ .

Table B1

Input Data for Example Application of DIFCD

Card No.*	Variables	Values
1	ID	EXAMPLE APPLICATION OF DIFCD
2	NMAX	15
	MMAX	15
	NS	2
3	KEY1	0
	KEY2	1
	KEY3	1
4	IPCN	1
	IPCL	1
	IPLT	0
5	NVERTS	1
6	YPOS(I)	49.0
7	IDEP	1
	DEPC	50.0
	DX	200.0
9	TSJ	0.0
	TSTOP	2,400.0
	DTL	600.0
	TJET	2,400.0
10	VDOT	5.0
	BC	0.5
	DJET	10.0
	ANGLE	90.0
	ROI	1.32
	BVOID	1.9
11	XBARGE	1,500.0
	ZBARGE	800.0
	SAI	0.0
	UB	0.0
12	PARAM	SAND
	ROAS	2.60
	CS	0.10

(Continued)

* As numbered and described in Appendix E.

Table B1 (Concluded)

Card No.	Variables	Values
12 (Continued)	VFALL	0.07
	VOIDS	0.8
	ICOHES	0
12	PARAM	SILT
	ROAS	2.60
	CS	0.10
	VFALL	0.02
	VOIDS	3.0
	ICOHES	0
13	PARAM	AMMONIA
	CINIT	100.0
	CBACK	0.0
17	NPROF	1
	NROA	2
	DTROA	2,400.0
18	YROA(I)	0.0
		50.0
19	RHOA(I)	1.0
		1.010
20	IFORM	3
21	DU1	45.0
	DU2	49.0
	UU1	0.0
	UU2	0.0
	DW1	45.0
	DW2	49.0
	WW1	0.5
	WW2	0.25

Table B2

Selected Computer Printout

DIFCD

```
FATE OF DREDGED MATERIAL DEPOSITED IN AN ESTUARY BY TIME LIMITED DISCHARGE FROM A MOVING BARGE OR
CONTINUOUS DISCHARGE FROM A FIXED PIPELINE


 EXAMPLE APPLICATION OF DIFCD


STORAGE ALLOCATION PARAMETERS FOLLOW...
NMAX MMAX   NS
 15   15     2


STORAGE ALLOCATION PARAMETERS FOLLOW...
NMAX MMAX   NS
 50


EXECUTION PARAMETERS FOLLOW...
KEY1  KEY2  KEY3  IPCN  IPCL  IPLT
  0     1     1     1     1     0


VERTICAL POSITIONS FOR OUTPUT FROM GAUSIAN CLOUD SCHEME
   49.00

NUMBER OF LONG TERM GRID POINTS IN Z-DIRECTION(NMAX) =  15
NUMBER OF LONG TERM GRID POINTS IN X-DIRECTION(MMAX) =  15

GRID SPACING (DX) =     200.00000
1         DEPTH GRID FOLLOWS...

 M N= 1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
 1   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
 2   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
 3   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
 4   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
 5   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
 6   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
 7   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
 8   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
 9   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
10   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
11   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
12   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
13   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
14   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
15   50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
```

(Continued)

(Sheet 1 of 10)

Table B2 (Continued)

```
     TIME PARAMETERS FOLLOW...
     TIME OF JET START =         .00 SECONDS AFTER START OF TIDAL CYCLE
     DURATION OF SIMULATION =    2400.00 SECONDS AFTER JET START
     DURATIONOF JET DISCHARGE =    2400.00 SECONDS
     LONG TERM TIME STEP (DTL) =     600.00 SECONDS


     DISCHARGE PARAMETERS...
     VOLUME RATE OF DISCHARGE (CUFT/SEC) =    5.000000
     INITIAL RADIUS OF JET (FT) =     .5000000
     DEPTH OF DISCHARGE NOZZLE (FT) =    10.00
     ANGLE OF DISCHARGE (DEGREES BELOW THE HORIZONTAL) =    90.00
     BARGE POSITION, XBARGE(FT) =  1500.
     BARGE POSITION, ZBARGE(FT) =  800.0
     COURSE(MEASURED ANTI-CLOCKWISE FROM POSITIVE X-AXIS) = 0.        DEGREES
     BARGE VELOCITY(FT/SEC) =  0.

     BULK PARAMETERS...
     DENSITY, ROI =    1.320000
     AGGREGATE VOIDS RATIO, BVOID =    1.900
1     THERE ARE  2 SOLIDS...PARAMETERS FOLLOW...
     DESCRIPTION  DENSITY(GM/CC)  CONCENTRATION(CUFT/CUFT)  FALL VELOCITY(FT/SEC)   VOIDS RATIO

       SAND        2.600              .1000                    .7000E-01        .8000
       SILT        2.600              .1000                    .2000E-01        3.000
      FLUID        1.000              .8000                   0.


     USE DEFAULT COEFFICIENTS
     ALPHA1     .0806     ALPHA2     .3536     BETA     .0000     CD    1.3000
     GAMA       .2500     CDRAG     1.0000     CFRIC    .0100     CD3     .2000     CD4    2.0000
     ALPHA3     .3536     ALPHA4     .0010     FRICTN     .0100     CM    1.0000
     ALAMDA     .0050     AKY0     .0500


     TWO VELOCITY PROFILES SPECIFIED IN X AND Z DIRECTIONS FOR --QUICK LOOKS--
     DEPTH ASSUMED CONSTANT AND VELOCITIES CONSIDERED STEADY IN TIME
     VELOCITY PROFILE PARAMETERS FOLLOW...
     DU1 =    45.0     DU2 =    49.0     UU1 =   0.         UU2 =   0.
     DW1 =    45.0     DW2 =    49.0     WW1 =    .500      WW2 =    .250
1     COMPUTE NEW JET-PLUME BEGINNING        .00 SECONDS AFTER START OF DISCHARGE

     AMBIENT VELOCITY DISTRIBUTION CORRESPONDS TO DTL ENDING AT SECOND     600.00 OF 90000 SECOND (25 HR) TIDAL CYCLE
```

(Continued)

(Sheet 2 of 10)

```
   COMPUTATIONAL INDICATORS...
NTRIAL    DINCR      IPLUNG  NUTRL   ISTEP
  1    1.000           1       0       24
  2    .1714           1       0       45
  3    .5510E-01       1       0       91
  4    .3582E-01       1       0      127


IPLUNG = 0 - INITIAL VALUE
       = 1 - BOTTOM ENCOUNTER IN JET
       = 2 - BOTTOM ENCOUNTER IN COLLAPSE
       = 4 - BOTTOM ENCOUNTER WITH SUBSEQUENT RISE OFF BOTTOM


NUTRL = 0 - INITIAL VALUE
      = 1 - JET PATH HORIZONTAL
      = 3 - DIFFUSIVE SPREADING GREATER THAN DYNAMIC


IF NTRIAL = 5 AND BOTH NUTRL AND IPLUNG = 0, PROGRAM TERMINATES
1      JET CONVECTION...
```

T	S	X	Y	Z	U	RADIUS	DEN-DIF	TRACER CONC.	FLUX OF SOLID	CONCENTRATION
.00	.00	.00	10.00	.00	6.366	.500	.3180E+00	.1000E+03	.5000E+00	.1000E+00
									.5000E+00	.1000E+00
.01	.04	.00	10.04	.00	6.350	.504	.3142E+00	.9880E+02	.5000E+00	.9880E-01
									.5000E+00	.9880E-01
.01	.09	.00	10.08	.00	6.326	.508	.3096E+00	.9738E+02	.5000E+00	.9738E-01
									.5000E+00	.9738E-01
.02	.15	.00	10.14	.00	6.297	.514	.3043E+00	.9570E+02	.5000E+00	.9570E-01
									.5000E+00	.9570E-01
.04	.23	.00	10.20	.00	6.263	.521	.2980E+00	.9373E+02	.5000E+00	.9373E-01
									.5000E+00	.9373E-01
.05	.31	.00	10.29	.00	6.223	.529	.2907E+00	.9143E+02	.5000E+00	.9143E-01
									.5000E+00	.9143E-01
.07	.42	.00	10.38	.00	6.176	.539	.2822E+00	.8878E+02	.5000E+00	.8878E-01
									.5000E+00	.8878E-01
.09	.55	.00	10.50	.00	6.120	.551	.2725E+00	.8572E+02	.5000E+00	.8572E-01
									.5000E+00	.8572E-01
.11	.71	.00	10.64	.00	6.056	.565	.2614E+00	.8224E+02	.5000E+00	.8224E-01
									.5000E+00	.8224E-01
.15	.90	.00	10.82	.01	5.981	.583	.2489E+00	.7833E+02	.5000E+00	.7833E-01
									.5000E+00	.7833E-01
.18	1.13	.00	11.03	.01	5.895	.604	.2351E+00	.7398E+02	.5000E+00	.7398E-01
									.5000E+00	.7398E-01
.23	1.41	.00	11.28	.02	5.798	.630	.2199E+00	.6922E+02	.5000E+00	.6922E-01
									.5000E+00	.6922E-01
.29	1.74	.00	11.58	.03	5.688	.661	.2035E+00	.6408E+02	.5000E+00	.6408E-01

(Continued)

(Sheet 3 of 10)

PS0

									.5000E+00	.3116E-02
9.82	36.14	.00	45.38	5.34	2.796	4.339	.6656E-02	.3022E+01	.5000E+00	.3022E-02
									.5000E+00	.3022E-02
10.06	36.80	.00	46.01	5.49	2.772	4.418	.6354E-02	.2942E+01	.5000E+00	.2942E-02
									.5000E+00	.2942E-02
10.29	37.45	.00	46.64	5.64	2.748	4.496	.6065E-02	.2866E+01	.5000E+00	.2866E-02
									.5000E+00	.2866E-02

1

COLLAPSE PHASE OF THE PLUME

COMPUTATIONAL INDICATORS...

NTRIAL	DINCR	IPLUNG	NUTRL	ISTEP	IBED	ILEAVE
1	1.000	1	3	245	127	999

IPLUNG = 0 - COLLAPSE IN THE WATER COLUMN
= 1 - BOTTOM ENCOUNTER IN JET
= 2 - BOTTOM ENCOUNTER IN COLLAPSE
= 4 - BOTTOM ENCOUNTER WITH SUBSEQUENT RISE OFF BOTTOM

NUTRL = 0 - INITIAL VALUE
= 3 - DIFFUSIVE SPREADING GREATER THAN DYNAMIC

IF NTRIAL = 5 AND NUTRL .NE. 3, PROGRAM TERMINATES

T	S	X	Y	Z	U	A	B	DEN-DIF	TRACER CONC.	SOLID VOL.	CONCENTRATION
10.29	37.45	.00	46.64	5.64	2.75	4.50	4.50	.6065E-02	.2866E+01	.1368E-01	.2866E-02
										.1368E-01	.2866E-02
10.32	37.52	.00	46.27	5.68	1.14	8.79	4.58	.6064E-02	.2866E+01	.2736E-01	.2866E-02
										.2736E-01	.2866E-02
10.44	37.66	.00	46.41	5.76	1.09	8.46	4.73	.6064E-02	.2866E+01	.2736E-01	.2866E-02
										.2736E-01	.2866E-02
10.56	37.79	.00	46.55	5.84	1.05	8.14	4.89	.6064E-02	.2866E+01	.2736E-01	.2866E-02
										.2736E-01	.2866E-02
10.68	37.91	.00	46.67	5.92	1.01	7.83	5.06	.6063E-02	.2865E+01	.2736E-01	.2865E-02
										.2736E-01	.2865E-02
10.80	38.04	.00	46.80	5.99	.97	7.55	5.23	.6063E-02	.2865E+01	.2736E-01	.2865E-02
										.2736E-01	.2865E-02
10.92	38.15	.00	46.91	6.07	.93	7.27	5.40	.6063E-02	.2865E+01	.2736E-01	.2865E-02
										.2736E-01	.2865E-02
11.04	38.27	.00	47.02	6.15	.90	7.01	5.57	.6063E-02	.2865E+01	.2736E-01	.2865E-02
										.2736E-01	.2866E-02

(Continued)

(Sheet 4 of 10)

Table B2 (Continued)

28.34	49.29	.00	49.65	16.88	.61	.82	28.50	.2622E-02	.2839E+01	.2305E-01 .1132E-01	.2391E-02 .1174E-02
28.56	49.42	.00	49.66	17.01	.61	.81	28.71	.2552E-02	.2838E+01	.2289E-01 .1105E-01	.2375E-02 .1147E-02
28.78	49.55	.00	49.66	17.14	.61	.80	28.92	.2483E-02	.2838E+01	.2274E-01 .1079E-01	.2359E-02 .1119E-02
29.00	49.68	.00	49.66	17.28	.61	.79	29.13	.2414E-02	.2837E+01	.2258E-01 .1053E-01	.2342E-02 .1092E-02
29.22	49.82	.00	49.67	17.41	.61	.78	29.33	.2345E-02	.2837E+01	.2243E-01 .1027E-01	.2326E-02 .1065E-02
29.44	49.95	.00	49.67	17.54	.61	.77	29.54	.2275E-02	.2837E+01	.2227E-01 .1001E-01	.2309E-02 .1038E-02
29.66	50.09	.00	49.68	17.68	.61	.76	29.74	.2206E-02	.2836E+01	.2211E-01 .9760E-02	.2292E-02 .1012E-02
										.2194E-01	.2275E-02

1 NEW CLOUDS CREATED IN BOOKS...

L	KC	CMASS	CEMAS	SC	THKC	TOPC	XC	ZC	TC
1	1	0.	0.	126.74	5.0072	44.993	1500.0	939.77	127.75
2	1	0.	0.	111.43	6.4373	43.563	1500.0	989.62	225.84
3	1	0.	0.	96.787	6.5611	43.439	1500.0	1039.5	323.94
4	1	0.	0.	82.850	5.4192	44.581	1500.0	1089.3	422.03
5	1	0.	0.	69.655	5.2563	44.744	1500.0	1139.1	520.12
6	1	39.940	0.	53.682	.76239	49.238	1500.0	1179.7	600.00
7	2	0.	0.	126.74	5.0072	44.993	1500.0	939.77	127.75
8	2	0.	0.	111.43	6.4373	43.563	1500.0	989.62	225.84
9	2	0.	0.	96.787	6.5611	43.439	1500.0	1039.5	323.94
10	2	0.	0.	82.850	5.4192	44.581	1500.0	1089.3	422.03
11	2	0.	0.	69.655	5.2563	44.744	1500.0	1139.1	520.12
12	2	39.940	0.	53.682	.76239	49.238	1500.0	1179.7	600.00
13	3	.13888E+07	0.	237.03	5.0072	44.993	1500.0	939.77	127.75
14	3	.13888E+07	0.	218.02	6.4373	43.563	1500.0	989.62	225.84
15	3	.13888E+07	0.	199.55	6.5611	43.439	1500.0	1039.5	323.94
16	3	.13888E+07	0.	181.64	5.4192	44.581	1500.0	1089.3	422.03
17	3	.13888E+07	0.	164.30	5.2563	44.744	1500.0	1139.1	520.12
18	3	.11309E+07	-.74506E-08	135.91	.76239	49.238	1500.0	1179.7	600.00

(Continued)

(Sheet 5 of 10)

Table B2 (Continued)

```
    SUMMARY OF  SAND    DISTRIBUTION AFTER     600.00 SEC.
    TOTAL SUSPENDED MATERIAL (CUFT) =     39.940
    TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     245.23

    MAX CONC IS  .00000000 OUTPUT SUPPRESSED AT   49.00 FT
1BOTTOM ACCUMULATION OF  SAND    (CUFT/GRID SQUARE) ,    600.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000         (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0   0   0   0   00000

   7 0000   0   0 196  49   0   0   0   0   0   0   00000

   8 0000   0   0   0   0   0   0   0   0   0   0   00000

   9 0000   0   0   0   0   0   0   0   0   0   0   00000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000000
1  SMALL CLOUDS... SAND
```

(Continued)

(Sheet 6 of 10)

Table B2 (Continued)

```
    SUMMARY OF  SAND    DISTRIBUTION AFTER    2400.00 SEC.
    TOTAL SUSPENDED MATERIAL (CUFT) =     39.940
    TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     1145.2

    MAX CONC IS  .00000000 OUTPUT SUPPRESSED AT   49.00 FT
1BOTTOM ACCUMULATION OF  SAND    (CUFT/GRID SQUARE) ,   2400.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000         (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0   0   0   0   00000

   7 0000   0  44 785 226  30   0   0   0   0   0   00000

   8 0000   0   0   0  30  30   0   0   0   0   0   00000

   9 0000   0   0   0   0   0   0   0   0   0   0   00000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 000000000000000000000000000000000000000000000000000
1  SMALL CLOUDS... SAND
```

(Continued)

(Sheet 7 of 10)

```
     SUMMARY OF  SILT    DISTRIBUTION AFTER    2400.00 SEC.
     TOTAL SUSPENDED MATERIAL (CUFT) =     39.940
     TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     1145.2

     MAX CONC IS  .00000000 OUTPUT SUPPRESSED AT   49.00 FT
1BOTTOM ACCUMULATION OF  SILT    (CUFT/GRID SQUARE) ,   2400.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000        (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0   0   0   0   00000

   7 0000   0  44 785 226  30   0   0   0   0   0   00000

   8 0000   0   0   0  30  30   0   0   0   0   0   00000

   9 0000   0   0   0   0   0   0   0   0   0   0   00000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000000
1  SMALL CLOUDS... SILT
```

(Continued)

(Sheet 8 of 10)

Table B2 (Continued)

```
    SUMMARY OF  AMMONIADISTRIBUTION AFTER      600.00 SEC.
    TOTAL TRACER IN SOLUTION (MG) =       .8075E+07
1CONCENTRATIONS ABOVE BACKGROUND OF  AMMONIA (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD      .00 SECONDS AFTER DUMP

              49.00 FT BELOW THE WATER SURFACE
 ...MULTIPLY DISPLAYED VALUES BY   1.000        (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0   0   0   0   00000

   7 0000   0   + .13 .01   0   0   0   0   0   0   00000

   8 0000   0   + .13 .01   0   0   0   0   0   0   00000

   9 0000   0   0   0   0   0   0   0   0   0   0   00000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000000
1  SMALL CLOUDS... AMMONIA
```

(Concluded)

(Sheet 9 of 10)

Table B2 (Concluded)

```
    SUMMARY OF  AMMONIADISTRIBUTION AFTER     2400.00 SEC.
    TOTAL TRACER IN SOLUTION (MG) =       .3356E+08
1CONCENTRATIONS ABOVE BACKGROUND OF  AMMONIA (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD      .00 SECONDS AFTER DUMP

              49.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY   1.000        (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

  2 0000000000000000000000000000000000000000000000000000

  3 0000   .   +   +   +   +   +   +   +   +   +  +0000

  4 0000   +   +   +   +   +   +   +   +   +   +  +0000

  5 0000   +   +   + .01 .02 .02 .02 .01   +   +  +0000

  6 0000   +   + .02 .06 .08 .07 .04 .02 .01   +  +0000

  7 0000   + .01 .22 .30 .27 .13 .08 .03 .01   +  +0000

  8 0000   + .01 .22 .30 .27 .13 .08 .03 .01   +  +0000

  9 0000   +   + .02 .06 .08 .07 .04 .02 .01   +  +0000

 10 0000   +   +   + .01 .02 .02 .02 .01   +   +  +0000

 11 0000   +   +   +   +   +   +   +   +   +   +  +0000

 12 0000   .   +   +   +   +   +   +   +   +   +  +0000

 13 0000   .   .   +   +   +   +   +   +   +   .  .0000

 14 0000000000000000000000000000000000000000000000000000
1  SMALL CLOUDS... AMMONIA

 N       X           Z          TMASS        TSIDE        TTHK        TTOP      FALL VEL       TEMAS
```

APPENDIX C: EXAMPLE APPLICATION OF DIFHD

1. To illustrate the application of DIFHD, a disposal operation from a stationary hopper dredge containing eight bins with pairs of bins opened sequentially is modeled.

Input Data

Operations information

2. A plan and side view of the hopper bins are illustrated in Figure C1. Disposal is assumed to occur from pairs of bins with the disposal from one pair essentially complete before disposal from the next pair begins. The total discharge takes 120 sec and occurs through bin doors with a cross-sectional area of 16 ft^2 which yields an equivalent circular geometry with a radius of 2.26 ft. The center-line distance between the bins is 14 ft. The discharge rate from each bin is taken to be 75 cfs. A total simulation period of 600 sec with a time-step of 300 sec is prescribed. The simulation period is arbitrary but should be small enough so that suspended material remains in the grid. The time-step is selected so that a small cloud does not travel more than one grid space Δx during the time-step.

3. A 15 × 15 grid with a Δx of 200 ft is employed. The location of the hopper dredge is 1,500 ft from the top of the grid and 1,500 ft from the left side of the grid. The loaded draft is 10.0 ft.

Dredged material information

4. The dredged material has an average bulk density of 1.32 g/cc and is composed of sand and clay solid fractions, each having a concentration of 0.10 ft^3/ft^3. The settling velocity of the sand is taken to be 0.07 fps while the clay is considered cohesive with the settling velocity computed internally using Equation 9 (main text). The aggregate void ratio is taken to be 2.26 with a value of 4.0 assumed for the clay and 0.8 for the sand. An ammonia concentration of 100 mg/ℓ exists in the bins with the ambient concentration taken to be zero.

Disposal site information

5. The disposal site is taken as a constant-depth site with a water depth of 75 ft and no bottom slope. The ambient current is 2.0 fps over the upper 70 ft of the water column and is directed from the left side of the grid

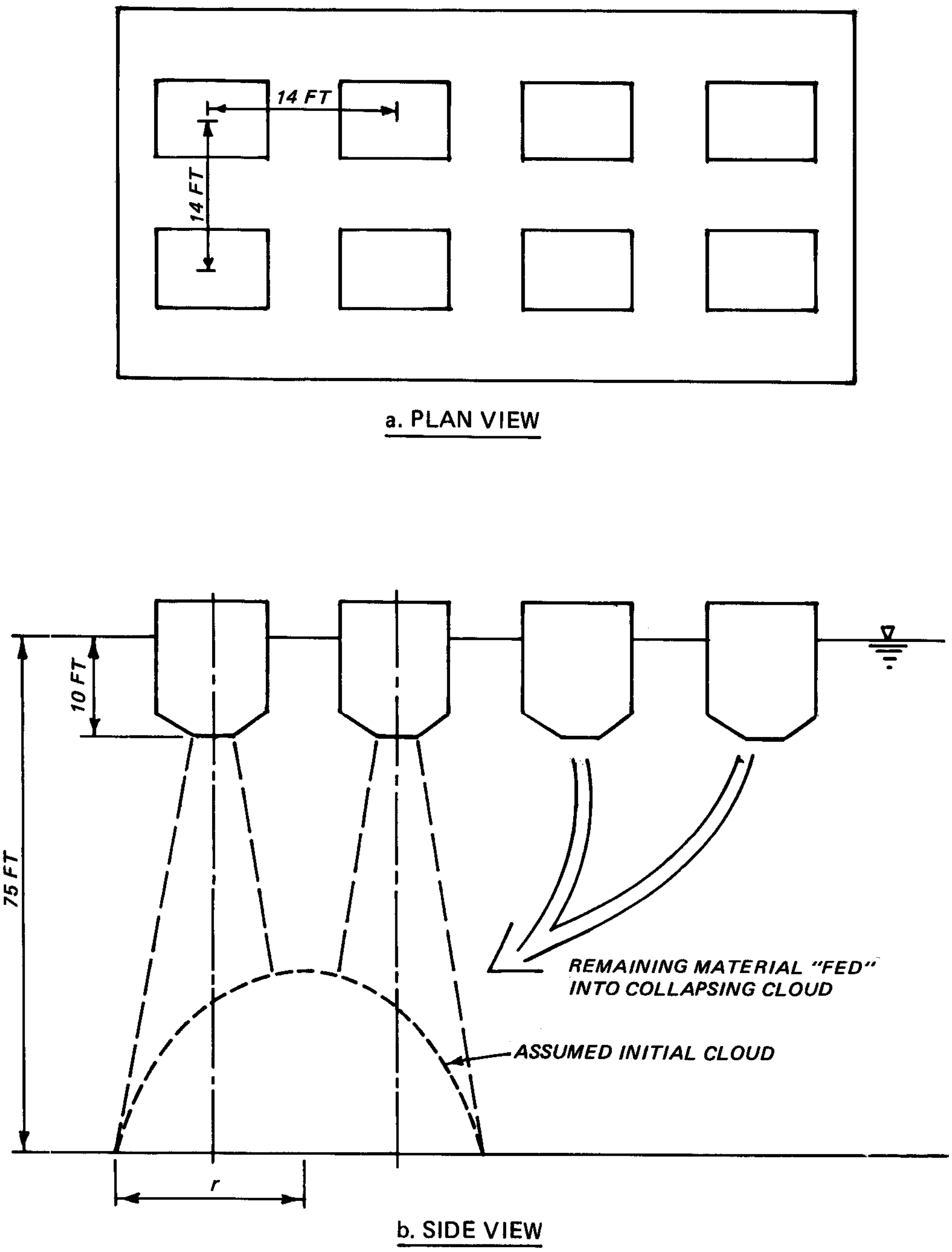

Figure C1. Hopper dredge disposal

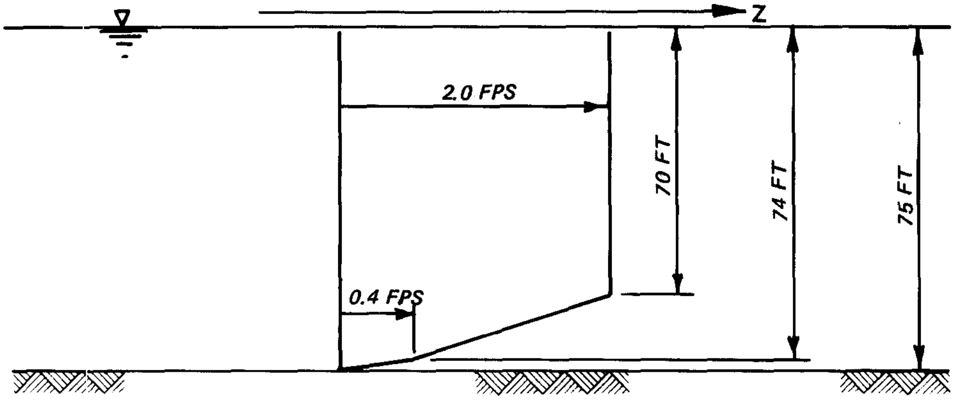

Figure C2. Ambient current velocity profile

to the right. The velocity then decreases linearly over the next 4 ft to 0.4 fps. This profile is illustrated in Figure C2. The ambient density is 1.00 g/cc at the surface and increases linearly to 1.01 g/cc at the bottom.

Coefficients

6. Default values are specified for all coefficients except the bottom friction, which is taken as 0.03.

7. The input data file required by DIFHD is presented in Table C1 and is the response to the input requirements presented in Appendix F.

Model Results

8. Output from DIFHD (Table C2) for the example problem is discussed in the following paragraphs. The output can be grouped into four categories. The first is an echo of much of the input data with the next two being time-histories of the descent and collapse phases. The final group of output is a time-history of the suspended sediment as well as the conservative constituent concentrations and bottom deposition on the horizontal grid for each solids fraction as well as the conservative constituent. All output is self-explanatory except for perhaps the computational indicators before both the descent and collapse phases and information concerning small clouds.

Computational indicators

9. Five trials, with a new value each trial for the integration step DS, are allowed in the descent computations. NTRIAL gives the value of the last trial. The counter ISTEP indicates the number of integration steps. At the end of each integration step, various checks are made to determine if the

jet convection phase has been successfully computed or if a new trial with a new integration step is required. The current trial is reconsidered if a neutrally buoyant position is computed which results in NUTRL = 1, if the bottom has been encountered, or if ISTEP > 600. Bottom encounter occurs if any of the three expressions below are satisfied, which results in IPLUNG = 1.

$$\mathrm{CY(ISTEP)} + 0.85 * \mathrm{BC(ISTEP)}\ \mathrm{SIN}\ \Theta_2 \geq \mathrm{H} \tag{C1}$$

$$\mathrm{CY(ISTEP)} + \mathrm{DS} \times \mathrm{COS}\ \Theta_2 \geq \mathrm{H} \tag{C2}$$

$$\mathrm{CY(ISTEP)} + 0.75 * \mathrm{BC(ISTEP)} \geq \mathrm{H} \quad \mathrm{IF} \quad \Theta_2 < 30\ \mathrm{deg} \tag{C3}$$

where

CY = vertical position of jet center line

ISTEP = number of integration steps

BC = jet radius

Θ_2 = angle between vertical and jet center line

H = water depth

DS = spatial integration step

Jet convection computations are considered complete if either NUTRL = 1 or IPLUNG = 1 and NTRIAL $\leq$ 5 and the number of integration steps ISTEP lies between 100 and 200. If a new trial is required, the jet computations are reinitiated but with the integration step set to be the old step multiplied by (DINCR * ISTEP/140) where DINCR can be input by the user. If after five trials a successful completion has not been realized, the program terminates.

10. Five trials with a new integration step DT for each trial are also allowed in the collapse computations. Once again the counter called ISTEP indicates the number of integration steps during each trial. A basic assumption in the use of DIFHD is that the bottom is encountered during the jet convection phase. Thus, if IPLUNG $\neq$ 1 when the collapse computations are initiated, the program terminates. While the cloud is collapsing on the bottom, if the bed reaction force becomes negative, the cloud leaves the bottom and IPLUNG = 4. In addition, the value of ISTEP when this happens is assigned to the variable ILEAVE, which has a default value of 999. If the discharge has been completed when an estimated diffusive spreading exceeds the rate of collapse, the variable labeled NUTRL is assigned a value of 3. For collapse

computations to be successful, NUTRL must have a value of 3 and the number of collapse integration steps given by (ISTEP - IBED) must be between 100 and 400. If these conditions are not met after five trials, the model run terminates.

11. Before the presentation of output on the horizontal grid, information on the small sediment clouds is given. The time of cloud creation, its centroid location, the length of a side of a square with equivalent area to the circular cloud's area, the location of the top of the cloud, its thickness, its total mass, and its entrained mass are presented for each cloud. The variables labeled NEWT and LAST give the values of ISTEP when the current and the previous small clouds were created, with LAST having a default value of 1.

Discussion

12. As can be seen from the computer printout, the jet of material from a bin reaches the bottom after 14.61 sec and has a radius of 17.04 ft. The resulting bottom collapse continues as long as the bottom cloud is fed by the continuous discharge of material from the remaining bins. After 600 sec, all of the solid material has been deposited on the bottom and the ammonia concentration has been diluted to a maximum of 0.51 mg/ℓ at 1.0 ft above the bottom.

Table C1

Input Data for Example Application of DIFHD

Card No.*	Variables	Values
1	ID	EXAMPLE APPLICATION OF DIFHD
2	NMAX	15
	MMAX	15
	NS	2
3	KEY1	1
	KEY2	0
	KEY3	1
4	IPCN	1
	IPCL	1
	IPLT	0
5	NVERTS	1
6	YPOS(I)	74.0
7	IDEP	1
	DEPC	75.0
	DX	200.0
9	TDUMP	0.0
	TSTOP	600.0
	DTL	300.0
	TDIS	120.0
10	VDOT	75.0
	BC	2.26
	DJET	10.0
	ROI	1.32
	BVOID	2.26
11	NBINS	2
	DBINS	7.0
12	XBARGE	1,500.0
	ZBARGE	1,500.0
	SLOPEX	0.0

(Continued)

* As numbered and described in Appendix F.

(Sheet 1 of 3)

Table C1 (Continued)

Card No.	Variables	Values
12 (Continued)	SLOPEZ	0.0
	XHOLE	0.0
	ZHOLE	0.0
	DHOLE	0.0
13	PARAM	SAND
	ROAS	2.60
	CS	0.10
	VFALL	0.07
	VOIDS	0.8
	ICOHES	0
13	PARAM	CLAY
	ROAS	2.60
	CS	0.10
	VFALL	0.001
	VOIDS	4.0
	ICOHES	1
14	PARAM	AMMONIA
	CINIT	100.0
	CBACK	0.0
15	ALPHA1	0.0806
	ALPHA2	0.3536
	BETA	0.0
	CD	1.3
	GAMA	0.25
	CDRAG	1.0
16	CFRIC	0.01
	CD3	0.10
	CD4	1.0
	ALPHAC	0.001
	FRICTN	0.03
	CM	1.0
17	ALAMDA	0.005
	AKYØ	0.05
18	NROA	2
19	Y(I)	0.0
		75.0

(Continued)

(Sheet 2 of 3)

Table C1 (Concluded)

Card No.	Variables	Values
20	ROA(I)	1.0
		1.01
21	IFORM	3
22	DU1	70.0
	DU2	74.0
	UU1	0.0
	UU2	0.0
	DW1	70.0
	DW2	74.0
	WW1	2.0
	WW2	0.4

(Sheet 3 of 3)

Table C2

Selected Computer Printout

DIFHD

```
FATE OF DREDGED MATERIAL DEPOSITED IN AN ESTUARY BY DISPOSAL FROM A STATIONARY HOPPER DREDGE

 EXAMPLE APPLICATION OF DIFHD

PROBLEM ALLOCATION PARAMETERS FOLLOW...
NMAX MMAX    NS
 15   15      2

EXECUTION PARAMETERS FOLLOW...
KEY1  KEY2  KEY3  IPCN  IPCL  IPLT
  1     0     1     1     1     0

VERTICAL POSITIONS FOR OUTPUT FROM GAUSSIAN CLOUD SCHEME FOLLOWS
   74.00

NUMBER OF LONG TERM GRID POINTS IN Z-DIRECTION(NMAX) =  15
NUMBER OF LONG TERM GRID POINTS IN X-DIRECTION(MMAX) =  15

GRID SPACING (DX) =     200.00000
1 DEPTH GRID FOLLOWS...
```

M N=	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
2	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
3	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
4	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
5	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
6	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
7	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
8	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
9	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
10	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
11	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
12	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
13	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
14	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
15	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.

(Continued)

(Sheet 1 of 12)

Table C2 (Continued)

```
DISCHARGE PARAMETERS...
VOLUME RATE OF DISCHARGE (CUFT/SEC) =    75.00000
INITIAL RADIUS OF JET (FT) =    2.260000
DEPTH OF DISCHARGE NOZZLE (FT) =    10.00
ANGLE OF DISCHARGE (DEGREES BELOW THE HORIZONTAL) =    90.00
BARGE POSITION, XBARGE (FT) =   1500.
BARGE POSITION, ZBARGE (FT) =  1500.

BULK PARAMETERS...
DENSITY, ROI =    1.320000
AGGREGATE VOIDS RATIO, BVOID =    2.260


BOTTOM SLOPE IN X-DIRECTION =        .00 DEG
BOTTOM SLOPE IN Z-DIRECTION =        .00 DEG
X DIMENSION OF HOLE =        .00 FT
Z DIMENSION OF HOLE =        .00 FT
AVERAGE DEPTH OF HOLE =        .00 FT

NUMBER OF BINS OPENED TOGETHER =   2
DISTANCE TO INCREASE DIAMETER OF BOTTOM CLOUD =      7.00 FT
1 THERE ARE  2 SOLIDS...PARAMETERS FOLLOW...
DESCRIPTION  DENSITY(GM/CC)  CONCENTRATION(CUFT/CUFT)  FALL VELOCITY(FT/SEC)  VOIDS RATIO

  SAND       2.600             .1000                  .7000E-01       .8000
  CLAY       2.600             .1000                  .1000E-02      4.000
 FLUID       1.000             .8000                 0.



USE READ IN COEFFICIENTS
ALPHA0     .2350   ALPHA1     .2350   ALPHA2     .0806   BETA     .3536   CD     .0000
GAMA      1.3000   CDRAG      .2500   CFRIC    .0100   CD3     .1000      CD4   1.0000
ALPHAC     .0010   FRICTN     .0300   CM     1.0000
ALAMDA     .0050   AKY0     .0500
```

(Continued)

(Sheet 2 of 12)

COMPUTATIONAL INDICATORS...

NTRIAL	DINCR	IPLUNG	NUTRL	ISTEP
1	1.000	1	0	14
2	.1000E+00	1	0	35
3	.2500E-01	1	0	70
4	.1250E-01	1	0	116

IPLUNG = 0 - INITIAL VALUE
= 1 - BOTTOM ENCOUNTER IN JET
= 2 - BOTTOM ENCOUNTER IN COLLAPSE
= 4 - BOTTOM ENCOUNTER WITH SUBSEQUENT RISE OFF BOTTOM

NUTRL = 0 - INITIAL VALUE
= 1 - JET PATH HORIZONTAL
= 3 - DIFFUSIVE SPREADING GREATER THAN DYNAMIC

IF NTRIAL = 5 AND BOTH NUTRL AND IPLUNG = 0, PROGRAM TERMINATES

1 JET CONVECTION...

T	S	X	Y	Z	U	RADIUS	DEN-DIF	TRACER CONC.	FLUX OF SOLID	CONCENTRATION
.00	.00	.00	10.00	.00	4.674	2.260	.3187E+00	.1000E+03	.7500E+01	.1000E+00
									.7500E+01	.1000E+00
.01	.03	.00	10.03	.00	4.700	2.260	.3168E+00	.9941E+02	.7500E+01	.9941E-01
									.7500E+01	.9941E-01
.01	.07	.00	10.06	.00	4.722	2.262	.3147E+00	.9877E+02	.7500E+01	.9877E-01
									.7500E+01	.9877E-01
.02	.10	.00	10.09	.00	4.745	2.265	.3125E+00	.9808E+02	.7500E+01	.9808E-01
									.7500E+01	.9808E-01
.03	.14	.00	10.13	.00	4.770	2.268	.3101E+00	.9731E+02	.7500E+01	.9731E-01
									.7500E+01	.9731E-01
.04	.19	.00	10.17	.00	4.796	2.271	.3074E+00	.9648E+02	.7500E+01	.9648E-01
									.7500E+01	.9648E-01
.05	.24	.00	10.22	.00	4.824	2.275	.3045E+00	.9558E+02	.7500E+01	.9558E-01
									.7500E+01	.9558E-01
.06	.29	.00	10.27	.00	4.854	2.280	.3014E+00	.9460E+02	.7500E+01	.9460E-01
									.7500E+01	.9460E-01
.07	.36	.00	10.32	.00	4.885	2.286	.2980E+00	.9353E+02	.7500E+01	.9353E-01
									.7500E+01	.9353E-01
.09	.42	.00	10.38	.00	4.917	2.292	.2943E+00	.9238E+02	.7500E+01	.9238E-01
									.7500E+01	.9238E-01
.10	.50	.00	10.45	.00	4.951	2.300	.2903E+00	.9113E+02	.7500E+01	.9113E-01
									.7500E+01	.9113E-01
.12	.58	.00	10.52	.00	4.986	2.309	.2860E+00	.8977E+02	.7500E+01	.8977E-01
									.7500E+01	.8977E-01
.14	.66	.00	10.60	.00	5.023	2.320	.2814E+00	.8832E+02	.7500E+01	.8832E-01

(Continued)

(Sheet 3 of 12)

13.81	50.85	.00	60.32	.00	3.107	16.328	.6345E-02	.2882E+01	.7500E+01	.2882E-02
									.7500E+01	.2882E-02
14.01	51.42	.00	60.88	.00	3.090	16.504	.6168E-02	.2836E+01	.7500E+01	.2836E-02
									.7500E+01	.2836E-02
14.21	51.98	.00	61.45	.00	3.074	16.681	.5996E-02	.2791E+01	.7500E+01	.2791E-02
									.7500E+01	.2791E-02
14.41	52.55	.00	62.01	.00	3.058	16.859	.5827E-02	.2747E+01	.7500E+01	.2747E-02
									.7500E+01	.2747E-02
14.61	53.11	.00	62.58	.00	3.041	17.037	.5661E-02	.2704E+01	.7500E+01	.2704E-02
									.7500E+01	.2704E-02

```
1       TIME STEP AT END OF JET =        .203
        TRACER CONCENTRATION FROM JET =     2.704
        DENSITY OF MATERIAL FROM JET =     1.014
        DISCHARGE RATE AT END OF JET =   5546.48
        VELOCITY IN X-DIRECTION =        .00
        VELOCITY IN Z-DIRECTION =        .00
1       COLLAPSE PHASE OF CLOUD
```

COMPUTATIONAL INDICATORS...

NTRIAL	DT	IPLUNG	NUTRL	ISTEP	IBED	ILEAVE
1	.2033	1	0	598	116	999
2	.3919	1	3	416	116	999

```
IPLUNG = 0-INITIALLY
         1-IF BOTTOM ENCOUNTERED IN CONV DESCENT
         2-IF BOTTOM ENCOUNTERED IN COLAPS
         4-IF CLOUD RISES FROM BOTTOM
NUTRL = 0-INITIALLY
        3-IF DIFFUSION GT DYNAMIC SPREADING
```

IF NTRIAL EQ 5 AND NUTRL NE 3 , PROGRAM TERMINATES

X AND Z MEASURED FROM BARGE POSITION

TIME	X	Y	Z	U	V	W	DEN-DIF	YA	XB	ZC	TRAC CONC	SOLID-VOL	CONCENTRATION
14.61	.00	62.58	.00	.00	3.04	.00	.5661E-02	17.04	41.07	41.07	.2704E+01	.4070E+02	.2704E-02
												.4070E+02	.2704E-02
16.57	.00	71.46	.02	.00	.97	.00	.5532E-02	9.45	69.70	69.70	.2917E+01	.6952E+02	.2894E-02
												.6971E+02	.2901E-02
18.53	.00	72.22	.02	.00	.25	.00	.5464E-02	7.41	94.92	94.92	.2848E+01	.9759E+02	.2793E-02
												.9821E+02	.2811E-02
20.49	.00	72.45	.03	.00	.08	.00	.5388E-02	6.79	113.54	113.54	.2812E+01	.1249E+03	.2726E-02
												.1262E+03	.2754E-02
22.45	.00	72.53	.03	.00	.03	.00	.5311E-02	6.57	128.38	128.38	.2790E+01	.1516E+03	.2673E-02
												.1538E+03	.2711E-02
24.41	.00	72.56	.03	.00	.01	.00	.5235E-02	6.51	140.86	140.86	.2775E+01	.1777E+03	.2628E-02
												.1809E+03	.2675E-02
26.37	.00	72.56	.03	.00	.00	.00	.5161E-02	6.51	151.77	151.77	.2765E+01	.2033E+03	.2589E-02
												.2077E+03	.2645E-02
28.33	.00	72.55	.04	.00	-.01	.00	.5090E-02	6.54	161.54	161.54	.2756E+01	.2283E+03	.2564E-02
												.2341E+03	.2618E-02
30.29	.00	72.53	.04	.00	-.01	.00	.5022E-02	6.59	170.46	170.46	.2750E+01	.2529E+03	.2528E-02
												.2602E+03	.2594E-02
32.25	.00	72.51	.04	.00	-.01	.00	.4956E-02	6.65	178.72	178.72	.2745E+01	.2770E+03	.2498E-02
												.2859E+03	.2571E-02
34.21	.00	72.48	.04	.00	-.01	.00	.4892E-02	6.71	186.43	186.43	.2741E+01	.3007E+03	.2463E-02

(Continued)

```
  126.31     .00  72.02    .13   .00   .00   .00   .2871E-02   7.96   389.90   389.90   .2710E+01   .1080E+04   .1705E-02
                                                                                                   .1245E+04   .1966E-02
  128.27     .00  72.01    .13   .00   .00   .00   .2838E-02   7.97   392.97   392.97   .2710E+01   .1091E+04   .1694E-02
                                                                                                   .1260E+04   .1957E-02
  130.23     .00  72.01    .13   .00   .00   .00   .2806E-02   7.98   396.01   396.01   .2710E+01   .1102E+04   .1683E-02
                                                                                                   .1276E+04   .1948E-02
  132.19     .00  72.00    .13   .00   .00   .00   .2775E-02   7.99   399.03   399.03   .2710E+01   .1113E+04   .1672E-02
                                                                                                   .1291E+04   .1938E-02

        FALL VELOCITY OF  CLAY    COMPUTED TO BE    .047000
1
        BEGIN LONG TERM SIMULATION OF FATE OF  SAND

 NEW CLOUD CREATED, NTCLD =     1
  T(SEC)        TX          TZ          TSIDE       TOP        TTHK       TMASS        TEMAS      NEWT      LAST
   30.68       1500.       1500.        152.6       73.88      1.125      23.95      0.           157       116

 NEW CLOUD CREATED, NTCLD =     1
  T(SEC)        TX          TZ          TSIDE       TOP        TTHK       TMASS        TEMAS      NEWT      LAST
   46.75       1500.       1500.        201.8       73.88      1.125      55.61      0.           198       157

 NEW CLOUD CREATED, NTCLD =     1
  T(SEC)        TX          TZ          TSIDE       TOP        TTHK       TMASS        TEMAS      NEWT      LAST
   62.82       1500.       1500.        238.9       73.88      1.125      78.78      0.           239       198

 NEW CLOUD CREATED, NTCLD =     1
  T(SEC)        TX          TZ          TSIDE       TOP        TTHK       TMASS        TEMAS      NEWT      LAST
   78.89       1500.       1500.        270.3       73.88      1.125      98.18      0.           280       239

 NEW CLOUD CREATED, NTCLD =     1
  T(SEC)        TX          TZ          TSIDE       TOP        TTHK       TMASS        TEMAS      NEWT      LAST
   94.95       1500.       1500.        298.2       73.88      1.125      115.0      0.           321       280

 NEW CLOUD CREATED, NTCLD =     1
  T(SEC)        TX          TZ          TSIDE       TOP        TTHK       TMASS        TEMAS      NEWT      LAST
   111.0       1500.       1500.        323.4       73.88      1.125      129.6      0.           362       321

 NEW CLOUD CREATED, NTCLD =     1
  T(SEC)        TX          TZ          TSIDE       TOP        TTHK       TMASS        TEMAS      NEWT      LAST
   127.1       1500.       1500.        346.6       73.88      1.125      142.3      0.           403       362
```

(Continued)

(Sheet 5 of 12)

Table C2 (Continued)

```
     SUMMARY OF  SAND    DISTRIBUTIONS AFTER     300.00 SEC.

     TOTAL SUSPENDED MATERIAL (CUFT) =    0.
     TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     1804.3

     MAX CONC IS  .00000000 OUTPUT SUPPRESSED AT   74.00 FT
1BOTTOM ACCUMULATION OF  SAND     (CUFT/GRID SQUARE) ,     300.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

   2 00000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0   0   0   0   00000

   7 0000   0   0   0   0 155 372 193 193   0   0   00000

   8 0000   0   0   0   0 155 348 193 193   0   0   00000

   9 0000   0   0   0   0   0   0   0   0   0   0   00000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 00000000000000000000000000000000000000000000000000
1  SMALL CLOUDS AT    300.00 SECONDS ELAPSED TIME
```

(Continued)

(Sheet 6 of 12)

Table C2 (Continued)

```
    SUMMARY OF  CLAY    DISTRIBUTIONS AFTER     300.00 SEC.

    TOTAL SUSPENDED MATERIAL (CUFT) =     54.800
    TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     1749.5
1CONCENTRATIONS ABOVE BACKGROUND OF  CLAY    (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD    300.00 SECONDS AFTER DUMP

             74.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY   .1000E-04    (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
 M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

  2 00000000000000000000000000000000000000000000000000000

  3 0000   0   0   0   0   0   0   0   0   0   0   00000

  4 0000   0   0   0   0   0   0   0   0   0   0   00000

  5 0000   0   0   0   0   .   +   +   +   .   0   00000

  6 0000   0   0   0   .   + .08 .23 .04   +   .   00000

  7 0000   0   0   0   . .03 1.1 2.9 .61 .01   .   00000

  8 0000   0   0   0   . .03 1.1 2.9 .61 .01   .   00000

  9 0000   0   0   0   .   + .08 .23 .04   +   .   00000

 10 0000   0   0   0   0   .   +   +   +   .   0   00000

 11 0000   0   0   0   0   0   0   0   0   0   0   00000

 12 0000   0   0   0   0   0   0   0   0   0   0   00000

 13 0000   0   0   0   0   0   0   0   0   0   0   00000

 14 00000000000000000000000000000000000000000000000000000
```

(Continued)

(Sheet 7 of 12)

Table C2 (Continued)

```
BOTTOM ACCUMULATION OF  CLAY    (CUFT/GRID SQUARE) ,     300.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000        (LEGEND... + = .LT. .01    . = .LT. .0001   0 = .LT. .000001)
  M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0   0   0   0   00000

   7 0000   0   0   0   0 115 344 212 212   0   0   00000

   8 0000   0   0   0   0 115 327 212 212   0   0   00000

   9 0000   0   0   0   0   0   0   0   0   0   0   00000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000
1  SMALL CLOUDS AT    300.00 SECONDS ELAPSED TIME

  N       X            Z            TMASS         TEMAS          TSIDE         TTHK         TTOP         VALL VEL
  1      1500.        1776.         54.80         0.              222.5        7.953         67.05          .047000
```

(Continued)

(Sheet 8 of 12)

Table C2 (Continued)

```
    SUMMARY OF  CLAY    DISTRIBUTIONS AFTER     600.00 SEC.

    TOTAL SUSPENDED MATERIAL (CUFT) =    0.
    TOTAL MATERIAL SETTLED TO BOTTOM (CUFT) =     1804.3
1BOTTOM ACCUMULATION OF  CLAY    (CUFT/GRID SQUARE) ,     600.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000        (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 0000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0 3.4 3.4 3.4 3.40000

   7 0000   0   0   0   0 115 344 212 216 3.4 3.4 3.40000

   8 0000   0   0   0   0 115 327 212 216 3.4 3.4 3.40000

   9 0000   0   0   0   0   0   0   0 3.4 3.4 3.4 3.40000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 0000000000000000000000000000000000000000000000000000
```

(Continued)

(Sheet 9 of 12)

Table C2 (Continued)

```
    SUMMARY OF  AMMONIA DISTRIBUTIONS AFTER     300.00 SEC

    TOTAL TRACER IN SOLUTION (MG) =       .51E+08
1CONCENTRATIONS ABOVE BACKGROUND OF  AMMONIA (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD    300.00 SECONDS AFTER DUMP

             74.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY   1.000        (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
 M N= 2   3   4   5   6   7   8   9  10  11  12  13  14

  2 000000000000000000000000000000000000000000000000000

  3 0000  0   0   0   0   0   0   0   0   0   0   00000

  4 0000  0   0   0   0   0   0   0   0   0   0   00000

  5 0000  0   0   0   0   .   .   +   +   .   0   00000

  6 0000  0   0   0   0   + .01 .07 .03   +   .   00000

  7 0000  0   0   0   .   + .16 .93 .41 .01   .   00000

  8 0000  0   0   0   .   + .16 .93 .41 .01   .   00000

  9 0000  0   0   0   0   + .01 .07 .03   +   .   00000

 10 0000  0   0   0   0   .   .   +   +   .   0   00000

 11 0000  0   0   0   0   0   0   0   0   0   0   00000

 12 0000  0   0   0   0   0   0   0   0   0   0   00000

 13 0000  0   0   0   0   0   0   0   0   0   0   00000

 14 000000000000000000000000000000000000000000000000000
1  SMALL CLOUDS AT    300.00 SECONDS ELAPSED TIME
```

(Continued)

(Sheet 10 of 12)

Table C2 (Continued)

```
    SUMMARY OF  AMMONIA DISTRIBUTIONS AFTER     600.00 SEC

    TOTAL TRACER IN SOLUTION (MG) =         .51E+08
1CONCENTRATIONS ABOVE BACKGROUND OF  AMMONIA (VOL RATIO OF SOLIDS---MG/L OF TRACER) IN THE CLOUD    600.00 SECONDS AFTER DUMP

               74.00 FT BELOW THE WATER SURFACE
...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01   . = .LT. .0001   0 = .LT. .000001)
 M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   .   .   00000

   4 0000   0   0   0   0   0   0   .   .   +   +   .0000

   5 0000   0   0   0   0   0   .   +   +   + .01   +0000

   6 0000   0   0   0   0   0   .   + .03 .12 .14 .040000

   7 0000   0   0   0   0   0   +   + .11 .46 .51 .150000

   8 0000   0   0   0   0   0   +   + .11 .46 .51 .150000

   9 0000   0   0   0   0   0   .   + .03 .12 .14 .040000

  10 0000   0   0   0   0   0   .   +   +   + .01   +0000

  11 0000   0   0   0   0   0   0   .   .   +   +   .0000

  12 0000   0   0   0   0   0   0   0   0   .   .   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 000000000000000000000000000000000000000000000000000
1  SMALL CLOUDS AT    600.00 SECONDS ELAPSED TIME
```

(Concluded)

(Sheet 11 of 12)

Table C2 (Concluded)

```
         FINAL DISTRIBUTIONS OF TOTAL SETTLED MATERIAL FOLLOW.....
1TOTAL ACCUMULATED SOLID VOLUME ON BOTTOM (CUFT/GRID SQR),      600.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   1.000          (LEGEND... + = .LT. .01    . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0 3.4 3.4 3.4 3.40000

   7 0000   0   0   0   0 270 716 406 409 3.4 3.4 3.40000

   8 0000   0   0   0   0 270 676 406 409 3.4 3.4 3.40000

   9 0000   0   0   0   0   0   0   0 3.4 3.4 3.4 3.40000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 000000000000000000000000000000000000000000000000000
1TOTAL THICKNESS (FT) OF NEW MATERIAL ON BOTTOM,    600.00 SECONDS AFTER DUMP
 ...MULTIPLY DISPLAYED VALUES BY   .1000E-01     (LEGEND... + = .LT. .01    . = .LT. .0001   0 = .LT. .000001)
  M N=  2   3   4   5   6   7   8   9  10  11  12  13  14

   2 000000000000000000000000000000000000000000000000000

   3 0000   0   0   0   0   0   0   0   0   0   0   00000

   4 0000   0   0   0   0   0   0   0   0   0   0   00000

   5 0000   0   0   0   0   0   0   0   0   0   0   00000

   6 0000   0   0   0   0   0   0   0 .02 .02 .02 .020000

   7 0000   0   0   0   0 2.1 5.8 3.3 3.3 .02 .02 .020000

   8 0000   0   0   0   0 2.1 5.5 3.3 3.3 .02 .02 .020000

   9 0000   0   0   0   0   0   0   0 .02 .02 .02 .020000

  10 0000   0   0   0   0   0   0   0   0   0   0   00000

  11 0000   0   0   0   0   0   0   0   0   0   0   00000

  12 0000   0   0   0   0   0   0   0   0   0   0   00000

  13 0000   0   0   0   0   0   0   0   0   0   0   00000

  14 000000000000000000000000000000000000000000000000000
1
```

(Sheet 12 of 12)

APPENDIX D: INPUT DATA FORMAT FOR DIFID

1. ID (10A8)

   ID = Descriptive title of run.

2. NMAX, MMAX, NS (3I5)

   NMAX = Number of grid points in the z-direction (left to right). (Max = 20).

   MMAX = Number of grid points in the x-direction (top to bottom). (Max = 20).

   NS = Number of solid fractions. (Max = 3).

3. KEY1, KEY2, KEY3, JBFC (4I5)

   KEY1 = 1 if user will input model coefficients, otherwise input 0.

   KEY2 = 1 if computations are terminated after convective descent, otherwise input 0.

   = 2 if computations are terminated after dynamic collapse, otherwise input 0.

   KEY3 = 1 if transport-diffusion computations for a conservative tracer are made, otherwise input 0.

   JBFC = 1 if liquid limit is known, otherwise input 0.

4. IPCN, IPCL, IPLT (3I5)

   IPCN = 1 if results from convective descent are to be printed, otherwise input 0.

   IPCL = 1 if results from the collapse phase are to be printed, otherwise input 0.

   IPLT = 0 if results from transport-diffusion computations are to be furnished at one-fourth, one-half, three-fourths, and end of total simulation time.

   = N if user will input N times at which transport-diffusion results are to be furnished. (Max = 12).

5. NVERTS (I5)

   NVERTS = Number of vertical positions where output from the transport-diffusion computations is desired. (Max = 4).

6. (YPOS(I), I = 1, NVERTS) (4F10.0)

YPOS(I) = Depth below the water surface in feet where output from the transport-diffusion computations will be provided. Will normally be in lower half of the water column.

7. IDEP, DEPC, DX (I5,5X,2F10.0)

IDEP = 1 if the water depth is constant, otherwise input 0.

DEPC = Constant water depth in feet. Enter 0.0 if IDEP = 0.

DX = Spatial step of the grid in feet. Typical values will be between 100 and 300 ft.

(If IDEP = 1, skip Card 8)

8. (DEPTH(N,M), N = 1, NMAX) (16F5.0)

DEPTH(N,M) = Water depths at grid points in feet. Enter from left to right and from top to bottom.

9. XBARGE, ZBARGE, SLOPEX, SLOPEZ, XHOLE, ZHOLE, DHOLE (7F10.0)

XBARGE = x-location of disposal on the grid in feet.

ZBARGE = z-location of disposal on the grid in feet.

SLOPEX = Slope of bottom at the disposal point in x-direction in degrees. A positive value results in movement of the cloud centroid toward the bottom of the grid.

SLOPEZ = Slope of bottom at the disposal point in z-direction in degrees. A positive value results in movement of the cloud centroid toward the right side of the grid.

XHOLE = x-dimension of bottom hole in feet. Leave blank if there is no hole.

ZHOLE = z-dimension of bottom hole in feet. Leave blank if there is no hole.

DHOLE = Depth of bottom hole in feet. Leave blank if there is no hole.

10. NROA (I5)

NROA = Number of points in ambient density profile. (Max = 5).

11. (Y(I), I = 1, NROA) (5F10.0)

Y(I) = Depth below the water surface in feet of density input.

12. (ROA(I), I = 1, NROA) (5F10.0)

ROA(I) = Ambient density in grams per cubic centimetres.

13. IFORM (I5)

IFORM = 3 if a constant-depth velocity profile will be input.

= 2 if a depth-averaged velocity profile, with a log distribution computed internally, will be input.

= 1 if a depth-averaged velocity profile with no vertical variation will be input.

(If IFORM ≠ 3, skip Card 14)

14. DU1, DU2, UU1, UU2, DW1, DW2, WW1, WW2 (8F10.0)

DU1, DU2, UU1, UU2 = Describes upper and lower U-component of constant-depth velocity profile (Figure 4). X-direction.

DW1, DW2, WW1, WW2 = Describes upper and lower W-component of constant-depth velocity profile (Figure 4). Z-direction.

If IFORM = 1 or 2, an Unformatted Velocity File (TAPE7) must be created as follows:

TUW

TUW = Time in seconds relative to a 90,000-sec tidal cycle when the following velocity data occur. Starting point on the tide for entry of data is arbitrary.

((U(N,M,), N = 1, NMAX), M = 1, MMAX), ((W(N,M), N = 1, NMAX), M = 1, MMAX)

U(N,M) = Vertically averaged velocity component in x-direction in feet per second.

W(N,M) = Vertically averaged velocity component in z-direction in feet per second.

15. TDUMP, TSTOP, DTL (3F10.0)

TDUMP = Time in seconds after beginning of tidal cycle when disposal is made.

TSTOP = Number of seconds simulation continues. Will normally be less than 3,600 sec.

DTL = Transport-diffusion time-step in seconds. Should select a value such that a small cloud will not travel more than one Δx during the time-step.

16. VOLM, DREL2, CU, CW, TREL (5F10.0)

VOLM = Total volume of dredged material in cubic yards.

DREL2 = Unloaded draft of disposal vessel in feet.

CU = Vessel speed in x-direction in feet per second.

CW = Vessel speed in z-direction in feet per second.

TREL = Time required to empty the scow in seconds.

17. ROO, BVOID, AMLL (3F10.0)

ROO = Bulk density of disposed material in grams per cubic centimetre.

BVOID = Void ratio of the disposed material after deposited on the bottom.

AMLL = Soil moisture content in multiple of liquid limit. Can leave blank if not known and JBFC is set to equal 0.

18. BARGL, BARGW (2F10.0)

BARGL = Vessel length in feet.

BARGW = Vessel width in feet.

19. PARAM, ROAS, CS, VFALL, VOIDS, ICOHES (A8,2X,4F10.0,I5)

PARAM = Description of solid fraction.

ROAS = Specific gravity of this type solid particle.

CS = Ratio of volume of this solid fraction to the total volume of the disposal.

VFALL = Settling velocity in feet per second of this type solid particle.

VOIDS = Void ratio for this solid fraction after deposit on the bottom.

ICOHES = 1 if this solid fraction is cohesive, otherwise input 0.

(Repeat Card 19 for each solid fraction)

(If KEY3 = 0, skip Card 20)

20. PARAM, CINIT, CBACK (A8,2X,2F10.0)

PARAM = Description of conservative constituent.

CINIT = Initial concentration of conservative constituent in the disposal in milligrams per litre.

CBACK = Background concentration of conservative constituent in the ambient water in milligrams per litre.

(If KEY1 ≠ 1, skip Cards 21-23)

21. ALPHAØ, BETA, CM, CD (4F10.0)

ALPHAØ = Entrainment coefficient for a turbulent thermal. Default = 0.235.

BETA = Settling coefficient. Default = 0.

CM = Apparent mass coefficient. Default = 1.0.

CD = Drag coefficient for a sphere. Default = 0.50.

22. GAMA, CDRAG, CFRIC, CD3, CD4, ALPHAC, FRICTN (7F10.0)

GAMA = Ratio of density gradient in the cloud to the ambient density gradient. Default = 0.25.

CDRAG = Form drag coefficient for the collapsing cloud. Default = 1.0.

CFRIC = Skin friction coefficient for the collapsing cloud. Default = 0.01.

CD3 = Drag coefficient for an ellipsoidal wedge. Default = 0.10.

CD4 = Drag coefficient for a plate. Default value is 1.0.

ALPHAC = Entrainment coefficient in collapse. Default = 0.001.

FRICTN = Friction coefficient between cloud and bottom. Default = 0.01.

23. ALAMDA, AKYØ (2F10.0)

ALAMDA = Dissipation parameter used in four-thirds law for horizontal diffusion. Default = 0.005 for an estuarine environment.

AKYØ = Vertical diffusion coefficient for unstratified water column. Default = 0.05 for an estuarine environment.

(If IPLT = 0, skip Card 24)

24. (TPRT(I), I = 1, IPLT) (8F10.0)

TPRT(I) = Time in seconds when output from the transport-diffusion computations will be furnished. Maximum number of times is 12. Use two lines if IPLT is greater than 8.

APPENDIX E: INPUT DATA FORMAT FOR DIFCD

1. ID (10A8)

   ID = Descriptive title of run.

2. NMAX, MMAX, NS (3I5)

   NMAX = Number of grid points in the z-direction (left to right). (Max = 20).

   MMAX = Number of grid points in the x-direction (top to bottom). (Max = 20).

   NS = Number of solid fractions. (Max = 3).

3. KEY1, KEY2, KEY3 (3I5)

   KEY1 = 1 if user will input model coefficients, otherwise input 0.

   KEY2 = 1 if the discharge is stationary, otherwise input 0.
   = 2 if computations are terminated after collapse.

   KEY3 = 1 if computations for a conservative tracer are made, otherwise input 0.

4. IPCN, IPCL, IPLT (3I5)

   IPCN = 1 if results from the convective descent phase are to be printed, otherwise input 0.

   IPCL = 1 if results from the collapse phase are to be printed, otherwise input 0.

   IPLT = 0 if results from transport-diffusion computations are to be furnished at one-fourth, one-half, three-fourths, and end of total simulation time.

   = N where N is the number of times output is requested from the transport-diffusion computations.

5. NVERTS (I5)

   NVERTS = Number of vertical positions where output from the transport-diffusion computations is desired. (Max = 4).

6. (YPOS(I), I = 1, NVERTS) (4F10.0)

YPOS(I) = Depth in feet below the water surface where output from the transport computations will be provided. Will normally be in lower half of the water column.

7. IDEP, DEPC, DX (I5,5X,2F10.0)

IDEP = 1 if the water depth is constant, otherwise input 0.

DEPC = Constant water depth in feet. Enter 0.0 if IDEP = 0.

DX = Spatial step of the grid in feet. Typical values will be between 100 and 300 ft.

(If IDEP = 1, skip Card 8)

8. (DEPTH(N,M), N = 1, NMAX) (16F5.0)

DEPTH(N,M) = Water depth at grid points in feet. Enter from left to right on the grid and from top to bottom.

9. TSJ, TSTOP, DTL, TJET (4F10.0)

TSJ = Time in seconds after the beginning of tidal cycle when disposal is initiated.

TSTOP = Number of seconds simulation will continue. Normally less than 3,600 sec after disposal stops.

DTL = Transport-diffusion time-step in seconds. Must be greater than time to end of collapse phase but small enough so that a small cloud does not travel more than one Δx during the time-step. Make a preliminary run with KEY2 = 2 and KEY3 = 0 to determine the collapse time.

TJET = Number of seconds the disposal continues.

10. VDOT, BC, DJET, ANGLE, ROI, BVOID (6F10.0)

VDOT = Volume rate of discharge in cubic feet per second.

BC = Initial jet radius in feet.

DJET = Depth of discharge source below the water surface in feet.

ANGLE = Angle of discharge source in degrees relative to horizontal.

ROI = Bulk density of disposed material in grams per cubic centimetre.

BVOID = Void ratio of the disposed material after deposited on the bottom.

11. XBARGE, ZBARGE, SAI, UB (4F10.0)

XBARGE = x-location of disposal on the grid in feet.

ZBARGE = z-location of disposal on the grid in feet.

SAI = Vessel course measured counterclockwise from positive x-axis. Positive x-axis is top to bottom.

UB = Vessel speed in feet per second.

12. PARAM, ROAS, CS, VFALL, VOIDS, ICOHES (A8,2X,4F10.0,I5)

PARAM = Description of solid fraction.

ROAS = Specific gravity of this type solid fraction.

CS = Ratio of volume of this solid fraction to the total volume of the disposal.

VFALL = Settling velocity in feet per second of this type solid particle.

VOIDS = Void ratio for this solid fraction after deposit on the bottom.

ICOHES = 1 if this solid fraction is cohesive, otherwise input 0.

(Repeat Card 12 for each solid fraction)

(If KEY3 = 0, skip Card 13)

13. PARAM, CINIT, CBACK (3F10.0)

PARAM = Description of conservative constituent.

CINIT = Initial concentration of tracer in milligrams per litre.

CBACK = Background concentration of conservative constituent in the ambient water in milligrams per litre.

(If KEY1 $\neq$1, skip Cards 14-16)

14. ALPHA1, ALPHA2, BETA, CD, CM (5F10.0)

ALPHA1 = Entrainment coefficient for a jet. Default = 0.0806.

ALPHA2 = Entrainment coefficient for a thermal. Default = 0.3536.

BETA = Settling coefficient. Default = 0.0.

CD = Drag coefficient for a cylinder. Default = 1.3.

CM = Apparent mass coefficient. Default = 1.0.

15. GAMA, CDRAG, CFRIC, CD3, CD4, ALPHA3, ALPHA4, FRICTN (8F10.0)

GAMA = Ratio of plume density gradient to the ambient density gradient. Default = 0.25.

CDRAG = Form drag coefficient of a collapsing elliptical cylinder. Default = 1.0.

CFRIC = Skin drag coefficient of a collapsing elliptical cylinder. Default = 0.01.

CD3 = Drag coefficient for an ellipsoidal wedge. Default = 0.20.

CD4 = Drag coefficient for a 2-D plate. Default value = 2.0.

ALPHA3 = Entrainment coefficient due to convection in the collapse phase. Default = 0.3536.

ALPHA4 = Entrainment coefficient due to collapse of the element. Default = 0.001.

FRICTN = Friction coefficient between cloud and bottom. Default = 0.01.

16. ALAMDA, AKYØ (2F10.0)

ALAMDA = Dissipation factor used in four-thirds law for horizontal diffusion. Default = 0.005 in an estuarine environment.

AKYØ = Vertical diffusion coefficient for unstratified water column. Default = 0.05 in an estuarine environment.

17. NPROF, NROA, DTROA (2I5,F10.0)

NPROF = Number of density profiles (Max = 5).

NROA = Number of points in ambient density profile. (Max = 5).

DTROA = Time in seconds between profiles. Input total simulation time (TSTOP) if NPROF = 1.

18. (YROA(I), I = 1, NROA) (5F10.0)

YROA(I) = Depth below the water surface in feet where density values are input.

19. (RHOA(I), I = 1, NROA) (5F10.0)

RHOA(I) = Ambient density in grams per cubic centimetre.

20. IFORM (I5)

IFORM = 3 if a constant-depth velocity profile will be input.

= 2 if a depth-averaged velocity profile, with a log distribution computed internally, will be input.

= 1 if a depth-averaged velocity profile with no vertical variation will be input.

(If IFORM ≠ 3, skip Card 21)

21. DU1, DU2, UU1, UU2, DW1, DW2, WW1, WW2 (8F10.0)

DU1, DU2, UU1, UU2 = Describes the U-velocity profile. (Figure 4).

DW1, DW2, WW1, WW2 = Describes the W-velocity profile (Figure 4).

If IFORM = 1 or 2, an Unformatted Velocity File (TAPE7) must be created as follows:

TUW

TUW = Time in seconds relative to a 90,000-sec tidal cycle when the following velocity data occur. Starting point on the tide for entry of data is arbitrary.

((U(N,M), N = 1, NMAX), M = 1, MMAX), ((W(N,M), N = 1, NMAX), M = 1, MMAX)

U(N,M) = Vertically averaged velocity component in x-direction in feet per second.

W(N,M) = Vertically averaged velocity component in z-direction in feet per second.

(If IPLT = 0 , skip Card 22)

22. (TPRT(I), I = 1, IPLT) (8F10.0)

TPRT(I) = Time in seconds when output from the transport-diffusion computations will be furnished. Maximum number of times is 12.

APPENDIX F: INPUT DATA FORMAT FOR DIFHD

1. ID (10A8)

   ID = Descriptive title of run.

2. NMAX, MMAX, NS (3I5)

   NMAX = Number of grid points in the z-direction (left to right). (Max = 20).

   MMAX = Number of grid points in the x-direction (top to bottom). (Max = 20).

   NS = Number of solid fractions. (Max = 3).

3. KEY1, KEY2, KEY3 (3I5)

   KEY1 = 1 if coefficients required in the computations will be input by user, otherwise input 0

   KEY2 = 1 if computations are terminated after convective descent, otherwise input 0.

   = 2 if computations are terminated after dynamic collapse, otherwise input 0.

   KEY3 = 1 if transport-diffusion computations for a conservative tracer are made, otherwise input 0.

4. IPCN, IPCL, IPLT (3I5)

   IPCN = 1 if results from the convective descent are to be printed, otherwise input 0.

   IPCL = 1 if results from the collapse phase are to be printed, otherwise input 0.

   IPLT = 0 if results from the transport-diffusion phase are to be printed at one-fourth, one-half, three-fourths, and end of total simulation time.

   = N if user will input N times at which transport-diffusion results are to be furnished. (Max = 12).

5. NVERTS (I5)

   NVERTS = Number of vertical positions where concentration output from the transport-diffusion computations is desired. (Max = 4).

6. (YPOS(I), I = 1, NVERTS) (4F10.0)

YPOS(I) = Depth in feet below the water surface where output from the transport-diffusion computations will be provided. Will normally be in lower half of the water column.

7. IDEP, DEPC, DX (I5,5X, 2F10.0)

IDEP = 1 if the water depth is constant, otherwise input 0.

DEPC = Constant water depth in feet. Enter 0.0 if IDEP = 0.

DX = Space step of the grid in feet. Typical values will be between 100 and 300 ft.

(If IDEP = 1, skip Card 8)

8. ((DEPTH(N,M), N = 1, NMAX), M = 1, MAX) (16F5.0)

DEPTH(N,M) = Water depths at grid points in feet. Enter from left to right and from top to bottom.

9. TDUMP, TSTOP, DTL, TDIS (4F10.0)

TDUMP = Time in seconds of the initiation of the disposal with respect to the beginning of the tidal cycle.

TSTOP = Duration of the simulation in seconds. Will normally be less than 3,600 sec.

DTL = Time-step for transport-diffusion computations. Must be greater than time to end of collapse. Make a preliminary run with KEY2 = 2 and KEY3 = 0.

TDIS = Time in seconds required to complete the discharge operation.

10. VDOT, BC, DJET, ROI, BVOID (5F10.0)

VDOT = Discharge flow rate in cubic feet per second.

BC = Radius of discharge opening in feet.

DJET = Loaded draft of the vessel in feet.

ROI = Bulk density of discharged material in grams per cubic centimetre.

BVOID = Void ratio of the disposed material after deposited on the bottom.

11. NBINS, DBINS (I5, 5X, F10.0)

NBINS = Number of bins opened simultaneously. Only one jet is computed in the convective descent phase; however, if NBINS > 1, the effect is included in the bottom collapse phase.

DBINS = Representative distance which increases the initial radius of the bottom collapsing cloud to account for NBINS jets forming the cloud, e.g., set equal to one-half the distance between bins in feet.

12. XBARGE, ZBARGE, SLOPEX, SLOPEZ, XHOLE, ZHOLE, DHOLE (7F10.0)

XBARGE = x-location of disposal vessel in feet.

ZBARGE = z-location of disposal vessel in feet.

SLOPEX = Slope of the bottom at the disposal point in x-direction in degrees. A positive value results in movement of the cloud centroid toward the bottom of the grid.

SLOPEZ = Slope of bottom at the disposal point in z-direction in degrees. A positive value results in movement of the cloud centroid toward the right side of the grid.

XHOLE = x-dimension of bottom hole in feet. Leave blank if there is no hole.

ZHOLE = z-dimension of bottom hole in feet. Leave blank if there is no hole.

DHOLE = Depth of bottom hole in feet. Leave blank if there is no hole.

13. PARAM, ROAS, CS, VFALL, VOIDS, ICOHES (A8, 2X, 4F10.0, I5)

PARAM = Description of solid fraction.

ROAS = Specific gravity of this type solid particle.

CS = Ratio of volume of this solid fraction to the total volume of disposed material.

VFALL = Settling velocity in feet per second of this type solid particle.

VOIDS = Void ratio for this solid fraction after deposit on the bottom.

ICOHES = 1 if this solid fraction is cohesive, otherwise input 0.

(Repeat Card 13 for each solid fraction)

(If KEY3 = 0, skip Card 14)

14. PARAM, CINIT, CBACK (A8, 2X, 2F10.0)

PARAM = Description of conservative constituent.

CINIT = Initial concentration of conservative constituent in the hopper in milligrams per litre.

CBACK = Background concentration of conservative constituent in the ambient water in milligrams per litre.

(If KEY1 = 0, skip Cards 15-17)

15. ALPHAØ, ALPHA1, ALPHA2, BETA, CD, GAMA, CDRAG (6F10.0)

ALPHAØ = Entrainment coefficient for a turbulent thermal. Default = 0.235.

ALPHA1 = Entrainment coefficient for jet. Default = 0.806.

ALPHA2 = Entrainment coefficient for 2-D thermal. Default = 0.3536.

BETA = Settling coefficient. Default = 0.0.

CD = Drag coefficient for a cylinder. Default = 1.3.

GAMA = Ratio of plume density gradient to ambient density gradient. Default = 0.25.

CDRAG = Form drag coefficient of the collapsing cloud. Default = 1.0.

16. CFRIC, CD3, CD4, ALPHAC, FRICTN, CM (6F10.0)

CFRIC = Skin friction coefficient for the collapsing cloud. Default = 0.01.

CD3 = Drag coefficient for an ellipsoidal wedge. Default = 0.10.

CD4 = Drag coefficient for a plate. Default = 1.0.

ALPHAC = Entrainment coefficient in collapse. Default = 0.001.

FRICTN = Friction coefficient between cloud and bottom. Default = 0.01.

CM = Apparent mass coefficient. Default = 1.0.

17. ALAMDA, AKYØ (2F10.0)

ALAMDA = Dissipation parameter in four-thirds horizontal diffusion law. Default = 0.005 in an estuarine environment.

AKYØ = Maximum value of vertical diffusion coefficient for unstratified water column. Default = 0.05 for an estuarine environment.

18. NROA (I5)

NROA = Number of vertical points in ambient density profile. (Max = 5).

19. (Y(I), I = 1, NROA) (5F10.0)

Y(I) = Depth below the water surface in feet of density input.

20. (ROA(I), I = 1, NROA) (5F10.0)

ROA(I) = Ambient density in grams per cubic centimetre.

21. IFORM (I5)

IFORM = 3 if constant-depth velocity profiles will be input.
2 if a depth-averaged velocity profile, with a log distribution computed internally, will be input.
1 if a depth-averaged velocity profile with no vertical variation will be input.

(If IFORM ≠ 3, skip Card 22)

22. DU1, DU2, UU1, UU2, DW1, DW2, WW1, WW2 (8F10.0)

DU1, DU2, UU1, UU2 = Describes upper and lower U-components of constant-depth velocity profile (Figure 4). X-direction.

DW1, DW2, WW1, WW2 = Describes upper and lower W-components of constant-depth velocity profile (Figure 4). Z-direction.

If IFORM = 1 or 2, an Unformatted Velocity File (TAPE7) must be created as follows:

TUW

TUW = Time in seconds relative to a 90,000-sec tidal cycle when the following velocity data occur. Starting point on the tide for entry of data is arbitrary.

((U(N,M), N = 1, NMAX), M = 1, MMAX), ((W(N,M), N = 1, NMAX), M = 1, MMAX)

U(N,M) = Vertically averaged velocity component in x-direction in feet per second.

W(N,M) = Vertically averaged velocity component in z-direction in feet per second.

(If IPLT = 0, skip Card 23)

23. (TPRT(I), I = 1, IPLT) (8F10.0)

TPRT (I) = Time in seconds when output from the transport-diffusion computations will be furnished. Maximum number of times is 12.